Combining cognitive and neuropsychological perspectives to examine the plasticity of executive functioning in healthy aging: Evidence from verbal fluency measures

Thesis

presented to the Faculty of Arts

of the University of Zurich

for the degree of Doctor of Philosophy

by

Christine Sutter

of Rebstein SG

Accepted in the fall semester 2012

on the recommendation of

Prof. Dr. Mike Martin and Prof. Dr. rer. nat. Lutz Jäncke

Zurich 2012

Acknowledgements

First and foremost, I would like to thank Prof. Dr. Mike Martin for giving me the opportunity and support to write this thesis. I am grateful for the inspiring conversations that led to new possibilities for approaching research questions. In addition, I also would like to thank Prof. Dr. Lutz Jäncke who provided a valuable insight to an interesting field of research with his excellent lectures during my studies.

Furthermore, I would like to express my deepest gratitude to Dr. Jacqueline Zöllig who encouraged me to undertake the research projects and supported me throughout their completion in countless ways. I am very grateful for her incredible dedication and helpful contributions.

I thank Martin, Peter and Verena who encouraged me throughout the entire PhD thesis as well as Ornella, Nina, and Monika who always had helpful words of support.

Moreover, I would like to thank my colleagues at the Department of Psychology for all their support. Many coffee breaks and lunches have brought entertainment and delight, which also led to a stimulating work environment.

Furthermore, I extend my deepest gratitude to my students who helped with data collection and whose profound interest and dedication has facilitated the publication of this work.

Finally, I would like to express my thanks to all participants for their interest in aging research and their patience during the assessments. Their remarks helped to drive my research forward.

Contents

List of Tables

List of Figures

1 Abstract

Negative age changes in cognition have been reported repeatedly. Executive functions, such as shifting and inhibition, as well as processing speed as a precondition for executive functions are among the most frequently mentioned. Consequently, great interest has emerged in finding ways to maintain or improve factors that are at an increased risk for cognitive change in healthy old age. However, training studies are hardly comparable because of a mixture of training paradigms used. The present work developed a paradigm that allows comparing the effects of training tasks targeting different cognitive functions. More precisely, the thesis pursued three goals. (1) It investigated the cognitive processes of executive functions using the same paradigm but varying the instruction of a task. (2) It further investigated training gains and transfer effects when using such tasks in a training intervention. (3) Finally, it investigated the association of transfer effects with changes in neurophysiological correlates. In study 1 the instruction of verbal fluency tasks (i.e., producing as many words as possible according to specified criteria) was varied to target different cognitive processes. Evidence demonstrated that all five verbal fluency subtests were associated with different cognitive variables. That is, processing speed, shifting, and inhibition were involved in three phonemic fluency subtests for which the specified criteria were letters, depending on the instruction used. Study 2 investigated training gains and transfer effects after three weeks of daily telephone-based training using the three phonemic fluency tasks. The findings revealed that participants trained in the task targeting shifting experienced the greatest training gains and transfer effects. Study 3 combined the identical training task with performance on an established task-switching paradigm to examine the effects on processes commonly assessed in task-switching (e.g., mixing costs and switch costs). Additionally, electrophysiological measures were applied. Evidence shows improved performance on mixing costs along with training-induced changes in parietal electrode sites. In conclusion, the present work shows that a paradigm in which the underlying cognitive processes were previously identified, allowed a direct comparison of the effects of three training tasks targeting executive functions. The task targeting shifting led to the greatest improvements in behavioral measures, corresponding to neurophysiological results. Implications of these findings together with suggestions for future research are discussed.

2 Introduction

Cognitive aging refers to age-related positive as well as negative changes in several higher order cognitive functions, such as learning, memory, planning, and problem solving (Nyberg & Bäckman, 2004). Many cognitive training interventions are trying to identify the ways to improve negative changes. Evaluation criteria for training studies are the size of the effects, their duration, and transfer to untrained tasks.

Various training approaches have been adopted (i.e., strategy-based, process-based, and multi-domain). In recent cognitive training studies with older adults, process-based and multi-domain training interventions obtained the largest effects (e.g., Basak, Boot, Voss, & Kramer, 2008; Dahlin, Nyberg, Bäckman, & Neely, 2008). However, findings of these training studies are difficult to compare, because they differ in the paradigms used. Therefore, in the present thesis a paradigm was developed, which allowed comparing the effects of three different training tasks targeting executive functions. Furthermore, process-based training interventions focus on a specific process targeted in training; therefore, transfer effects remain relatively specific. Typically, transfer is found on tasks that involve the same underlying process as the training task. On the other hand, in multi-domain training interventions, transfer on a broad range of tasks is identified. However, the underlying processes targeted by the training often remain unclear (Lustig, Shah, Seidler, & Reuter-Lorenz, 2009). Accordingly, the present work combines the advantages of both approaches in a short-term non-traditional training intervention to improve cognitive performance in healthy old age.

Verbal fluency is used as training task to investigate this training intervention. Verbal fluency tests are frequently used in cognitive aging research to assess word production (Kempler, Teng, Dick, Taussig, & Davis, 1998; Sutin et al., 2011). The task requires individuals to produce as many words as possible within a limited time following a specified criterion (i.e., letter or category). Verbal fluency is particularly suitable for the present thesis, as it comprises the subtests initial letter fluency, animal naming, excluded letter fluency, and phonemic and semantic switching fluency, which will be discussed in more detail later.

Thus, the overall aim of the present thesis is to develop a paradigm, which allows comparing the effects of training tasks targeting different cognitive functions. That is, a non-traditional training design is used with verbal fluency as training task. Before designing such intervention, the first study investigates verbal fluency subtests and their relations to cognitive processes (study 1). This task analysis helps to identify training and transfer tasks for the subsequent training design. Based on the findings of the first study, three subtests were selected to investigate training gains as well as transfer effects (study 2). In an additional training study using the same training design, behavioral data were combined with electrophysiological data in order to receive further information of cognitive processes altered by training (study 3).

The thesis begins by presenting an overview of age-related changes in cognitive performance in Chapter 2. These findings are then related to contemporary theoretical models of cognitive aging to illustrate factors that might account for these changes. Furthermore, different ways of improving cognitive functions, such as strategy-based, process-based, and multi-domain training interventions as well as interventions combining behavioral and neurophysiological data are outlined. Verbal fluency as a measure of executive functions as well as age-related differences on this measure are presented at the end of this chapter. In Chapter 3, three main research questions are specified. The three studies described in Chapter 4 address the proposed research questions. Chapter 5 provides a general discussion on the findings of the three studies and suggestions for future research.

3 Theoretical background

3.1 Age-related changes in cognitive performance

Behavioral findings provide some evidence for age-related changes in basic perceptual and cognitive abilities (Park et al., 2002; Verhaeghen & Cerella, 2002). Declines have been repeatedly found in tasks of fluid intelligence, such as processing speed, working memory, long term memory, and reasoning. On the other hand, stability or even performance increase in tasks related to crystallized ability, for example vocabulary and general knowledge, has also been found with advancing age. To illustrate, Park et al. (2002) found in a cross-sectional study negative effects of age on processing speed, working memory, and long-term memory, but positive effects of age on knowledge or vocabulary. Thus, maintenance as well as impairment in cognitive functions has been found. Frequently, age-related cognitive impairments are identified in cognitive functions subsumed under the unifying construct of executive functions[1]. Therefore, in the following sections the construct of executive functions is discussed in more detail.

Executive functions refer to control processes responsible for regulating other cognitive processes important for goal-directed behavior (Head, Rodrigue, Kennedy, & Raz, 2008). The construct encompasses mental flexibility as well as the ability to filter interference and anticipate consequences (Stuss & Knight, 2002). In the neuropsychological assessment, executive functions also play an important role. Several measures of executive functions have been commonly used, such as the Stroop Test, the Trail Making Test, the Wisconsin Card Sorting Test, the Tower of London, or verbal fluency measures (Salthouse, Atkinson, & Berish, 2003). Neuropsychologists refer to these tests as measures of executive frontal functions, relating them to the site in the human brain to which these are frequently ascribed (Salthouse, 2005). On the other hand, cognitive psychologists refer to these as measures of executive functioning, emphasizing the cognitive processes that these measures capture (Luszcz, 2011). The different perspectives are depicted below in Figure 1 (adapted from Salthouse et al., 2003). From the neuropsychological perspective it shows different tests that are used to assess executive or frontal functions. In contrast, the cognitive perspective is interested in the underlying cognitive processes associated with executive functions.

[1] In the present thesis executive functions are included among higher level cognitive functions.

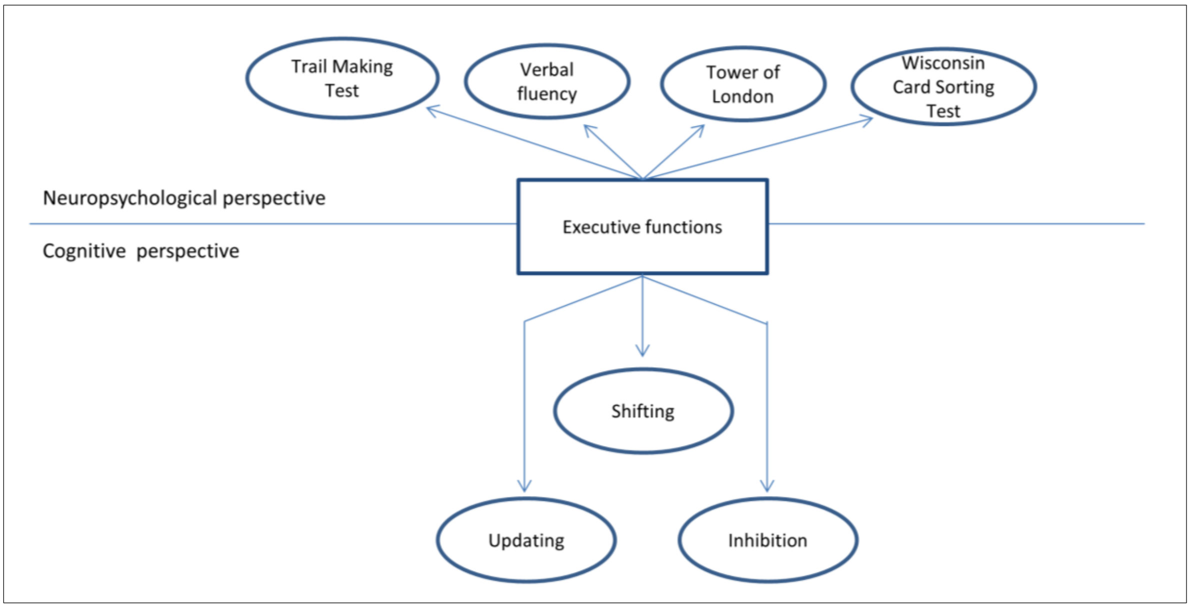

Figure 1. Cognitive measures (neuropsychological perspective) and underlying cognitive processes (cognitive perspective) of executive functions.

Note. Simplified version adapted from Salthouse et al. (2003).

Taking this cognitive perspective Miyake et al. (2000) proposed a model emphasizing three distinguishable yet interrelated dimensions of executive functions: shifting, inhibition, and updating. Interestingly, age-related cognitive impairments have frequently been reported in all of these dimensions. To illustrate, regarding shifting, the existing research indicates larger switch costs in older adults compared to young adults (Kramer, Hahn, & Gopher, 1999; Kray, Li, & Lindenberger, 2002). Furthermore, increasing difficulties in old age have been found in information updating in working memory (De Beni & Palladino, 2004) as well as in inhibitory control (Hasher, Stoltzfus, Zacks, & Rypma, 1991).

Overall, the cognitive perspective focuses on the processes underlying each task. In the neuropsychological assessment, it is also known that not all tests involve the same cognitive processes. Therefore, a fine-grained task analysis is necessary to identify the cognitive processes underlying successful task performance. Until now, different tests have been used to assess different cognitive processes (e.g., the Tower of London to assess planning and the Wisconsin Card Sorting Test to assess set-shifting). However, these tests differ not only in the cognitive processes that are involved but also in the paradigms used. In the present thesis, different cognitive processes are assessed by applying different subtests but with the same paradigm.

3.2 Theoretical models of cognitive aging

Several theoretical models can explain age-related changes in cognitive performance. Earlier models focused mainly on the deficit of a particular process. To illustrate, the processing speed theory of aging states that processing speed decreases with increasing age, which in turn decreases other cognitive functions, because many cognitive tests involve a speed component (Salthouse, 1996). Speed is therefore a precondition for the use of executive functions. Similarly, the inhibitory deficit theory refers to a reduction in functional working memory capacity with increasing age due to decreased efficiency of inhibitory processes, which reduces the ability to reject irrelevant information in working memory (Hasher & Zacks, 1988). A further deficit-oriented approach links changes in performance to changes in the brain. The frontal lobe hypothesis of aging (Dempster, 1992; West, 1996) states that age-related changes in the frontal lobes of the brain are associated with a decrease in executive functions. As mentioned above, executive functions are usually assigned to the frontal lobes (Smith & Jonides, 1999). Performance on several cognitive functions subsumed under the term executive functions, decreases with advancing age. That is, in the long term, deficits in structure could also involve behavioral changes.

There are further imaging-based models, linking brain activity patterns and performance in healthy old age. Two brain activity patterns are common (Dennis & Cabeza, 2008). First, an age-related decrease in occipital activity and increase in prefrontal activity have been repeatedly found and referred to as Posterior-Anterior Shift in Aging (PASA; Grady et al., 1994). It has been suggested that these deficits of occipital activation have been compensated by recruiting higher order cognitive functions, which are located in the prefrontal cortex and lead to an increase in the prefrontal area (Dennis & Cabeza, 2008). Second, an increase in activation has also been found in the prefrontal cortex of older adults when performing a verbal memory task. That is, in addition to the left prefrontal activity found in both young and old adults, there is evidence for further activation in the right frontal cortex in older adults exhibiting a high performance level (Dennis & Cabeza, 2008). This finding led to a construction of a new model, proposing less lateralization of prefrontal activity in older adults during cognitive performance, in short, Hemispheric Asymmetry Reduction in Older Adults (HAROLD; Cabeza, 2002). However, while the earlier models are generally deficit-oriented, the imaging based models are limited to the functions of frontal lobes.

Newer findings have emphasized the notion that a single cognitive basis may not sufficiently explain cognitive performance in old age (Luszcz, 2011) and are less deficit-oriented. More recent theories are more general and comprehensive, for example the theory of cognitive reserve (Stern, 2002) and the scaffolding theory of aging and cognition (Park & Reuter-Lorenz, 2009). Cognitive reserve refers to the amount of brain damage that can exist before clinically relevant cognitive impairment is found (Stern, 2002). Stern distinguished between cognitive reserve, that is, the ability to optimize normal performance, and compensation, that is, the ability to maximize performance after brain damage, using brain structures that were previously not involved. Besides cognitive reserve, where the brain is actively coping with brain damage, brain reserve refers to a more passive process of the brain. That is, once a critical threshold is reached, functional deficits can occur (Stern, 2002). Furthermore, the theory extends the former models and explains cognitive performance in old age by considering lifestyle factors. In addition to perceiving intelligence, education, and occupation as important factors that provide cognitive reserve, engagement in leisure activities are assumed to lead to stable performances or even reversal of age-related changes (Scarmeas & Stern, 2003). Park and Reuter-Lorenz (2009) proposed a similar model. The scaffolding theory of aging considers behavioral, structural, and functional changes. It assumes that aging entails structural and functional changes in the brain. Similar to the cognitive reserve theory, it further assumes that the brain creates “neural scaffolds that serve as supportive structures that preserve cognitive function.” (Park & Bischof, 2011, p. 112). The property of the brain to change as a result of experience is called neuroplasticity (Jäncke, 2009). An effective means to investigate the feasibility of changing brain and behavior in old age provide cognitive training interventions (Hertzog, Kramer, Wilson, & Lindenberger, 2009).

3.3 Cognitive training interventions in older adults

There is a growing interest in the effectiveness of cognitive training interventions to postpone or attenuate age-related decrease in cognitive functions in healthy old age (Martin, Clare, Altgassen, Cameron, & Zehnder, 2011). Currently, training interventions are classified as strategy-based training interventions, process-based training interventions, or multi-domain training interventions. The following sections review these three training approaches.

3.3.1 Strategy-based training

In strategy-based training interventions, after teaching cognitive strategies, participants are usually given time to practice (Noack, Lovden, Schmiedek, & Lindenberger, 2009). In the past, different mnemonic techniques have been successfully employed; among the most popular are the method of loci and the face-name mnemonic (Yesavage, Sheikh, Friedman, &

Tanke, 1990). Mnemonic strategy interventions have been found to lead to improved performance compared to control conditions. Young age of participants, short training sessions, pre-training, and training in group sessions were the most influential determinants of success (for a meta-analysis, see Verhaeghen, Marcoen, & Goossens, 1992).

A more recent study investigated strategy training intervention in healthy older adults. In the ACTIVE study (Ball et al., 2002) a large, randomized control trial design was used (N = 2832). Participants were randomly assigned to one of three training groups (i.e., verbal episodic memory, reasoning, processing speed) or to a no-contact control. Training consisted of 10 sessions that provided strategies, followed by a period for extended practice. To 60 % of the participants, four booster sessions were offered 11 month later. Even though there were large training gains for the processing speed group and small to medium effects for the reasoning and memory group, transfer to untrained cognitive tasks was lacking. In a five-year follow-up study (Willis et al., 2006), participants in the reasoning training group reported less difficulty in performing instrumental activities of daily living compared to the control group. Furthermore, throughout the five years, each of the three intervention groups preserved the performance level on the targeted cognitive ability.

Thus, the findings of this study suggest that cognitive interventions based on strategies with healthy older adults provide a useful tool to improve cognitive functioning as well as to maintain abilities important for independent living. However, evidence for transfer to other cognitive abilities is lacking. This finding, along with the finding that older adults seem to have difficulties using strategies due to incompliance and incorrect strategy use, or doubts about the benefit of using the strategies (Verhaeghen & Marcoen, 1996), has led to a change in the designs of cognitive training interventions (Noack et al., 2009). Furthermore, strategy-based training interventions are based on the assumption that strategies improve performance on tasks on which participants perform poorly (Lustig et al., 2009). However, none of the above mentioned cognitive models, such as deficit-oriented or frontal lobe models, provides the basis for an improvement in cognitive performance through strategy use (except for the processing speed theory of aging, which could be linked to the speed training task in the ACTIVE study. This task, however, is based on a process-based training task).

3.3.2 Process-based training

Process-based training interventions adopt a different approach. Instead of teaching strategies, the focus lies on extended practice of training tasks, which involve cognitive processes associated mostly with executive functions. Especially working memory training has been incorporated in several training studies. For example, Dahlin, Nyberg, et al. (2008) examined the effects of a computer-based training, targeting updating in young and older participants. After five weeks of training, significant training gains were found in both groups. However, transfer effects to a 3-back task that also required updating, were only found in young adults. Similarly, Li et al. (2008) studied the effectiveness of a 45-day working memory training. Besides training gains on a spatial working memory task, they also found transfer to untrained spatial and numerical n-back tasks in younger and older adults but no transfer to complex span tasks. Furthermore, Buschkuehl et al. (2008) investigated working memory training in a sample of 80 year-old adults. After three month of twice-weekly training, the authors reported training gains in working memory and transfer to a visual episodic memory task. Even though the studies differed in their findings regarding transfer, it seems that there is evidence for plasticity in working memory performance, even in old age. However, the studies also differed in the definition of transfer, which indicates that until now, there has been no consensus on the transfer taxonomy. Nevertheless, the question of transfer is important, as the ultimate goal in training studies is to maintain or increase cognitive performance in general.

Besides working memory, prior studies have targeted other executive processes as well. For example, the trainability of dual-task and task-switching ability has been investigated. In dual-tasks, participants are asked to perform two simple tasks, such as discriminating two letters and two different tones (Zelinski, Dalton, & Smith, 2011). Both tasks performed at the same time, usually decrease accuracy and reaction time, which is referred to as dual-task costs. Frequently, there is also an age effect, with older adults exhibiting larger costs compared to younger adults (Zelinski et al., 2011). However, several training studies have identified a reduction in dual-task costs after dual-task training (Bherer et al., 2005; Kramer et al., 1999). In a study by Bherer et al. (2005), younger and older participants trained in dual-task performance exhibited greater reduction in dual-task costs as well as transfer to two other tasks compared to a no-contact control group. However, these results should be interpreted with caution, as no active control group was included that would have controlled for the effects of repetition of a single task (Noack et al., 2009). Another study investigated the effects of a task-switching training in children, young adults, and older adults (Karbach & Kray, 2009). After four training sessions, training gains were found in similar task-switching tasks as well as transfer to tasks measuring inhibitory control, verbal and visual working memory, and reasoning.

Taken together, process-based training approaches seem to provide evidence for large training gains in addition to partial transfer effects. Regarding interventions targeting executive functions, the frontal lobe theory of aging has often been used as underlying model (e.g., Dahlin, Nyberg et al., 2008). The strength of the process-based approach is the knowledge of the mechanisms involved in task performance, which helps determine tasks with the same underlying transfer processes (Lustig et al., 2009). However, more studies are needed to investigate long-term effects. Furthermore, from the participants' perspective, process-based trainings could be considered rather monotonous and integrating training activities into everyday life might be difficult. Therefore, multi-domain training interventions provide an alternative approach.

3.3.3 Multi-domain training

In contrast to the two approaches presented above, other studies trained several cognitive abilities simultaneously. To illustrate, Basak and colleagues (2008) targeted planning, working memory and shifting in a real-time video game intervention with older adults. Training consisted of playing the commercially available strategy game "the Rise of Nations" for 23 hours over the course of 8 weeks. In this game, the authors assumed that the above mentioned cognitive processes were required for successful performance. For example, they were needed to build cities and to fight enemies. Indeed, after training, the results revealed greater improvements in reasoning, task-switching, working memory, and spatial ability among the trained participants compared to a no-contact control group. However, the study did not include an active control group; therefore, several other factors might have contributed to these effects (Noack et al., 2009).

Noice, Noice, and Staines (2004) investigated the effectiveness of a multi-domain training intervention in which older community-dwelling participants were assigned to a theater arts intervention, a visual arts intervention, or a no-contact control group. After four weeks of theater training, participants in the theater arts intervention group showed significantly greater improvements in recall and problem-solving as well as psychological well-being compared to the other two groups.

In a still ongoing Synapse Intervention Trial (Lodi-Smith & Park, 2011), participants were randomly assigned to one of eight groups. The first four groups, so-called "productive engagement groups", acquired a new activity, for example, quilting, digital photography, the two activities combined, or quilting combined with exercise, in 14 weeks of 15 hours per week intervention. The four remaining groups, a social control group spending time in passive activities, such as going on field trips, a placebo control group doing passive activities at home, such as reading a book, an exercise control group, and a no-treatment control group were used as controls. Significant effects were expected for the following cognitive functions: processing speed, visual-spatial and verbal working memory, long-term memory inductive reasoning, and mental control. A pilot study was conducted with a relatively small number of participants (quilting N = 30; digital photography N= 9) who completed 8 weeks of quilting or digital photography training. Participants in the quilting group exhibited improved performance in processing speed and visual-spatial working memory while participants in the digital photography group showed improved performance in long-term memory compared to the no-contact control group.

Overall, similar to the findings of process-based interventions, some of the multi-domain cognitive training interventions produced large improvements in both the trained and transfer tasks. These findings suggest that non-traditional training interventions targeting several cognitive domains simultaneously can enhance cognitive functions in older adults. That is, the idea behind these training interventions is to provide stimulating activities that lead to new neural activations or scaffolds (Scarmeas & Stern, 2002; Lodi-Smith & Park, 2011). Moreover, this approach to training involves an important aspect, that is, enjoyment and motivation (Boot & Blakely, 2011). With these training designs, participating in daily training sessions could be easier than in monotonous computer-based programs that are sometimes used for process-based training interventions. Furthermore, multi-modal training interventions typically use longer training periods and additionally include training activities that easily could be continued after participating in the intervention (e.g., theater, photography, etc.). Therefore, this training approach has a greater potential for integrating training activities into lifestyle. However, a disadvantage of this approach lies in the fact that the mechanisms behind the training improvements are not ultimately clear. This, in turn, would be important for selecting the appropriate transfer tasks (Lustig et al., 2009).

3.3.4 Neural correlates of training-induced changes

Cognitive training studies constitute a valuable means to investigate the extent of plasticity by examining changes in behavioral performance and its connection to neural mechanisms (Lindenberger, 2008). Several studies investigated the link between behavioral improvements through training interventions and changes in neural correlates. To illustrate, different patterns of event-related potentials (ERPs) have been identified when comparing older adults receiving a familiarization intervention with the sequence of stimuli in a prospective memory paradigm compared with a control group (Zöllig, Mattli, Sutter, Aurelio, & Martin, 2012). Correspondingly, alterations in ERPs have been found during stimulus encoding after training in early visual processing (Berry et al., 2010). Besides these findings from EEG studies, functional magnetic resonance imaging (fMRI) has also been used to investigate the effects of cognitive training studies. For example, a previous study identified a key role of the striatum in the transfer to cognitive tasks (Dahlin, Neely, Larsson, Bäckman, & Nyberg, 2008). During five weeks, younger and older adults were trained in a computer-based updating task. After training, greater activity in the striatum was found on the training tasks for older adults and on the training and transfer tasks for younger adults.

Behavioral and neurophysiological data do not provide the same information. In cognitive training research, behavioral data allow researchers to directly measure the participant’s performance, whereas neurophysiological data provide new information about the processes that benefitted from training. Furthermore, neurophysiological changes could precede behavioral changes.

Although transfer to untrained tasks tends to be more difficult to demonstrate in older than in younger adults, findings from both EEG and fMRI studies emphasize training-induced changes detected at the level of the brain. As Lustig et al. (2009) proposed, the ideal training intervention might be based on the strengths of the three approaches described above (i.e., strategy-based, process-based, and multi-domain training interventions) in combination with neuroimaging data in order to attain the most effects.

Following this overview on age-related changes in healthy old age and the potential of cognitive training interventions, the next chapter describes a cognitive measure that is essential for the present thesis. Verbal fluency as a measure of executive functions comprises several subtests, which will be used as a means to investigate a non-traditional training intervention.

3.4 Verbal fluency measures

Language, as one of the most important and efficient products, is assumed to be the origin of thoughts as well as higher order cognitive functions that account for metacognitive executive functions (Vygotsky, 1962). Furthermore, language as an instrument of internal representations helps transferring knowledge (Ardila, 2008). In everyday life, linguistic competence is important, as we generate new ideas through language. A good measure of communication skills is verbal fluency, as it is defined as the ease with which a person can produce words (Baldo & Shimamura, 1998). In general, verbal fluency requires participants to produce as many words as possible within a limited time, beginning with a designated letter (i.e., words starting with s) or category (i.e., animals). Besides the total amount of words produced, other values reflect the number of repetitions and rule breaking errors (i.e., words with the same word stem, words that would not appear in a newspaper, and proper names; Aschenbrenner, Tucha, & Lange, 2000). Verbal fluency measures are commonly used within neuropsychological batteries to assess cognitive performance of both clinical and healthy older adults (Kempler et al., 1998; Sutin et al., 2011).

The two most frequently used verbal fluency measures are animal naming and initial letter fluency (Tombaugh, Kozak, & Rees, 1999). Several other verbal fluency measures, such as phonemic switching fluency (i.e., alternating between two given initial letters), semantic switching fluency (i.e., alternating between two categories), and excluded letter fluency (i.e., words not containing a specified letter, e.g., words without e) have received less attention in earlier research (Bryan, Luszcz, & Crawford, 1997).

3.4.1 Verbal fluency as a measure of executive functions

Verbal fluency performance is thought to measure frontal or executive functions (Phillips, 1999). Common to all measures of executive function is that they are effortful and novel (in the sense of strategies involved). Reduced performance on verbal fluency measure is generally associated with executive dysfunction (Phillips, 1999). Based on the construct validity of several measures of executive functions, verbal fluency has previously been identified as the best measure of executive functions (Salthouse et al., 2003).

Although verbal fluency is among the most frequently used tests in neuropsychological test batteries, little is known about cognitive processes involved in performing this task (Randolph, Braun, Goldberg, & Chase, 1993). For successful verbal fluency performance, the following processes have been speculated to be involved: working memory, inhibition, processing speed, episodic memory, shifting as well as verbal knowledge (Henry, Crawford, & Phillips, 2004; Salthouse et al., 2003). However, there is considerable lack of research to provide actual evidence of an association among these cognitive processes. Furthermore, since there is more than one subtest of this measure, it is likely that not all of these cognitive functions might be involved to the same extent. To illustrate, phonemic switching fluency might involve shifting, because the task requires switching between two different letters; in contrast, excluded letter fluency might involve inhibition to a greater extent, as the task requires inhibiting words containing a specified letter. By focusing only on the two most commonly used task variants, we are likely to lose much information about performance on this task. Figure 2 shows a simplified version of how different cognitive processes could be related to verbal fluency, based on Figure 1 integrating both the neuropsychological and cognitive perspective.

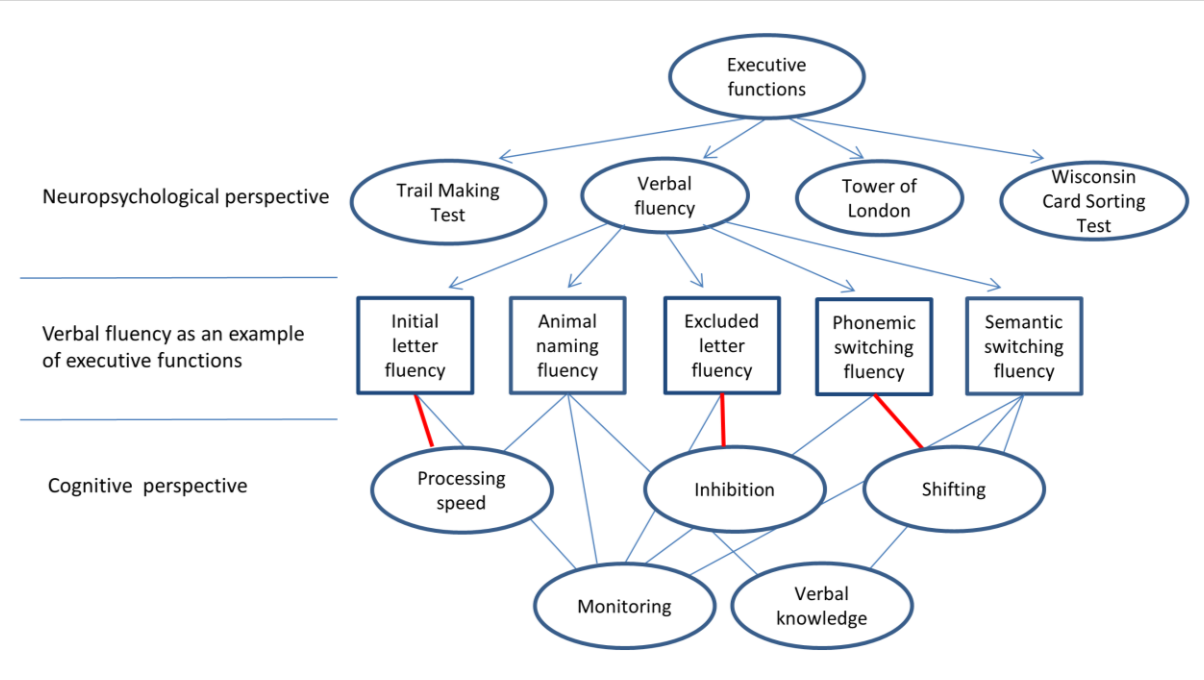

Figure 2. Possible relation between several verbal fluency measures and different cognitive processes.

Note. The red dashes indicate potentially stronger associations between verbal fluency subtests and cognitive processes.

3.4.2 The influence of age on verbal fluency performance

Older adults often report suffering from 'word finding' difficulties. As mentioned above, executive functions are susceptible to the effects of aging, and verbal fluency measures, too, have been identified to be highly age sensitive. Older adults tend to produce fewer words compared to younger adults (Hultsch, Hertzog, Small, McDonald-Miszczak, & Dixon, 1992). Initial letter fluency seems to be less susceptible to the effects of age in contrast to animal naming, in which age effects are commonly found (Tombaugh et al., 1999). Furthermore, more demanding fluency tasks, such as phonemic or semantic switching fluency as well as excluded letter fluency, might also produce stronger age effects (Bryan et al., 1997). In addition, most of the above-mentioned executive processes that might be associated with verbal fluency performance have been found to be negatively affected by advancing age, with the exception of verbal knowledge, which has been shown to have a positive effect with age (Park et al., 2002). Overall, verbal fluency has a great potential to explore current research questions in cognitive aging research.

In conclusion, the review of the theoretical background emphasizes several interesting aspects. (1) Evidence suggests a decline in executive functions in healthy old age. Cognitive training interventions provide an effective means for investigating plasticity in executive functions. However, the findings of training interventions are difficult to compare when using different paradigms. What is needed is a training activity that would involve the same paradigm but target different executive functions and which is motivating and easy to integrate in everyday life. This would make comparisons more interpretable, and it would combine the advantages of process-based and multi-domain training interventions. (2) Verbal fluency represents a suitable tool to design such a training intervention. However, there is considerable lack of research on different verbal fluency subtests and the underlying cognitive processes. If the relations of these variables were better understood, verbal fluency could be used to design such training intervention. (3) Furthermore, the combination of behavioral training studies and neurophysiological evidence is suggested to provide further information on the processes involved. These aspects led to the three main research questions investigated in the present work and specified in the following chapter.

4 Research questions

The following three research questions build upon another. To investigate a new short-term training approach, verbal fluency lends itself well as training task. The task has high diagnostic utility and is a commonly used measure in cognitive aging research (Fisk & Sharp, 2004; Kempler et al., 1998). The first research question explores basic cognitive processes related to verbal fluency performance. More precisely, it considers the contribution of different cognitive processes associated with five verbal fluency subtests. These findings are important for designing a cognitive training intervention. The second research question investigates the benefits of such a verbal fluency training intervention. It examines the effectiveness of a non-traditional training approach, using three verbal fluency subtests as training tasks assessed over the telephone. Finally, based on the findings from the second research question, the most effective verbal fluency training is used to investigate the effects on specific processes of a task-switching paradigm in the third research question. Moreover, behavioral data is combined with the application of EEG to better explore the training-induced changes in brain and behavior.

4.1 Question 1: Relation between cognitive functions and five variations of verbal fluency measures

In addition to the two verbal fluency subtests which are most commonly used - initial letter and animal naming (Hultsch et al., 1992; Kempler et al., 1998) - there are further verbal fluency subtests on which little is known; for example, excluded letter fluency, phonemic switching fluency, and semantic switching fluency. Furthermore, as outlined above, it is assumed that successful verbal fluency performance requires the combination of several cognitive processes such as inhibition, working memory, verbal knowledge, episodic memory, and processing speed (Henry & Crawford, 2004; Sutin et al., 2011; Weiss et al., 2003). However, this is based on assumptions and evidence from empirical studies is lacking. Therefore, the question arises whether these subtests differ in the extent to which different cognitive processes are associated. To illustrate, it could be assumed that while both, initial letter and animal naming, require processing speed, animal naming could involve to a greater extent access to the semantic network, which is reflected in verbal knowledge (Woods, 1975). Furthermore, inhibitory capacity might be necessary for excluded letter fluency performance, and shifting for phonemic or semantic switching fluency performance (see Figure 2).

Therefore, a different pattern of involved cognitive processes is expected for each subtest. These findings are essential in order to know which cognitive function will be targeted when applying verbal fluency as a training task. Hence, the following research question is addressed: 1) Do the five verbal fluency subtests initial letter fluency, animal naming, excluded letter fluency, phonemic switching fluency, and semantic switching fluency differ in their association with cognitive variables? This study combines the neuropsychological perspective (i.e., verbal fluency as a frequently used measure to assess executive functions) and the cognitive perspective (i.e., investigating processes involved). Furthermore, in this study, we will control for age, gender, education, and subclinical depression as well as investigate the extent to which the relations between these subtests and cognitive variables differ with prolonged task duration.

4.2 Question 2: Specificity of training effects using three variations of verbal fluency targeting processing speed, shifting, and inhibition

After having analyzed which cognitive functions are related to the five verbal fluency subtests, the second research question investigates the improvement of verbal fluency and other cognitive performance measures among healthy older adults. As noted above, of the two currently used approaches, process-based and multi-domain training interventions, both seem to show evidence for large training gains in addition to partly remarkable transfer effects (e.g., Basak et al., 2008; Dahlin, Nyberg, et al., 2008). However, both approaches have disadvantages. While in process-based interventions mostly monotonous computer-based tasks are used (Boot & Blakely, 2011), the difficulty in multi-domain interventions is to know which processes are targeted in training. Therefore, for the second empirical study, we designed a training intervention which combines both training approaches. That is, the second empirical study aims at the evaluation of a training intervention with task variation targeting different cognitive processes. By using initial letter fluency, phonemic switching fluency, and excluded letter fluency as training tasks, we intend to target some of the cognitive processes that have been identified to be associated with performance on these tests in the first study (i.e., processing speed, shifting, and inhibition). In addition, we developed a training intervention which is short and easy to integrate into the everyday activities of older adults and which is applied over the telephone. This non-traditional training approach is especially convenient for older adults that are not comfortable working with computers. Thus, the second study addresses the following research question: In which of the three training tasks each targeting a specific cognitive function (processing speed, shifting and inhibition) can the largest effects as well as transfer to untrained tasks be identified?

4.3 Question 3: EEG correlates of phonemic switching fluency training targeting shifting

After having analyzed the effectiveness of a verbal fluency intervention, the follow-up study examines more closely performance of the training group that demonstrates the most benefits from training. That is, based on the results addressing question 2, the third research question addresses whether verbal fluency training would lead to benefits in specific processes of an established task-switching paradigm. As the phonemic switching group showed the most benefits from training and since shifting, besides other processes, has previously been associated with performance on this task (Cauthen, 1978), in study 3, we analyze commonly assessed processes in a task-switching paradigm (e.g., mixing costs and switch costs) that could be affected. Previous research found that switching between different tasks is especially reflected in an increasing reaction time, because shifting attention and changing cognitive task-sets requires effortful control (e.g., Rogers & Monsell, 1995). Subsequent studies on task-switching and dual-task training have found successful training gains and transfer effects in young and older adults (Bherer et al., 2005; Karbach & Kray, 2009). In addition, there is evidence that training-induced changes can be detected using electrophysiological measures (Berry et al., 2010; Maclin et al., 2011). Thus, the third research question aims at identifying whether there is evidence for these training-induced changes in electrophysiological data. Combining both behavioral and neurophysiological measures will provide further information on the cognitive processes that benefitted from training. Hence, a task-switching paradigm was applied that allowed the investigation of behavioral and electrophysiological data.

5 Empirical studies

In this chapter, three studies are presented that investigate verbal fluency and its potential as a cognitive training intervention in healthy old adults. Results are discussed at the end of each study as well as in a general discussion in the following chapter.

5.1 Study 1: Five verbal fluency subtests and their relations to cognitive functions in healthy old age[2]

5.1.1 Introduction

Verbal fluency is commonly tested in both the context of aging research and clinical settings (Sutin et al., 2011). Several different subtests of verbal fluency have been developed, all of which are easy to administer as no reading or writing by participants is needed (Kempler et al., 1998). The two most frequently used verbal fluency subtests are initial letter fluency and animal naming. Initial letter fluency requires that participants generate as many words as possible beginning with a specified letter (e.g., words starting with the letter 'S'), whereas animal naming asks participants to produce animal names. Other variants of verbal fluency subtests involve alternating between two initial letters (i.e., phonemic switching fluency) or between two categories (i.e., semantic switching fluency), which are also referred to as alternating fluency (Epker, Lacritz, & Munro Cullum, 1999), or generating words not containing a specified letter (i.e., excluded letter fluency; Bryan et al., 1997). Although some studies have examined verbal fluency in healthy old age (Bryan et al., 1997), there is a lack of studies investigating and comparing performance in different subtests, particularly including the latter three measures (i.e., phonemic switching fluency, semantic switching fluency, and excluded letter fluency).

In addition, different task durations are used to assess verbal fluency performance which makes it difficult to compare findings between studies. Typically, it is measured using the total number of words produced in one minute (e.g., Tombaugh et al., 1999). This brief assessment time clearly is an advantage when limited time is available or in the diagnostic evaluation of disorder-related cognitive performance (e.g., following neurological damage or with Alzheimer's disease; Henry & Crawford, 2004). Alternatively, verbal fluency

[2] A similar version of this chapter has been submitted for publication to "Neuropsychology" (Sutter, Zöllig, & Allemand).

performance is sometimes assessed across several minutes. For example, in the German version of the word fluency test (Regensburg Word Fluency Test [RWT]; Aschenbrenner et al., 2000), norms are available for both one minute and two minutes. Other studies use an assessment time of three minutes (Chen, Chen, Chan, Lam, & Lieh-Mak, 2000). In this regard, it has been suggested that, when performance differences are subjected to examination, they may be larger when longer task durations are evaluated (Aschenbrenner et al., 2000). Therefore, extending the assessment time of verbal fluency performance to three minutes might provide useful information (e.g., in a clinical setting comparing patients with schizophrenia and healthy controls see Elvevåg, Weinstock, Akil, Kleinman, & Goldberg, 2001). However, regarding healthy old adults there is a lack of studies comparing verbal fluency performance over the course of several minutes (i.e., comparing performance within the first minute against performance in the third minute).

Verbal fluency performance has been studied further in relation to several background variables, such as age, gender, and education (Tombaugh et al., 1999). Regarding age, older adults tend to produce fewer words than younger adults (Hultsch et al., 1992), a difference that seems to be greater for semantic fluency than phonemic fluency (Brickman et al., 2005). With respect to phonemic fluency, a greater age-related decline has been identified for excluded letter fluency versus initial letter fluency (Bryan et al., 1997). These findings are contrary to those of other studies, in which no age-related differences were revealed for several verbal fluency measures (e.g., Parkin, Walter, & Hunkin, 1995). On the subject of gender most studies have identified no association with phonemic or semantic fluency (Brickman et al., 2005; Tombaugh et al., 1999). Finally, in terms of education, findings point to an association between higher education and better performance on several verbal fluency measures (Kempler et al., 1998; Shores, Carstairs, & Crawford, 2006; Tombaugh et al., 1999). In addition to these somewhat inconsistent findings, studies are lacking that investigate all of these background variables in a sample of healthy older adults.

A further subject characteristic, although less commonly considered as background variable, is depression. Symptoms of depression have been found to inhibit performance on cognitive tests (Sutin et al., 2011). Henry and Crawford (2005) conducted a meta-analysis on verbal fluency deficits in depression and found that depressed patients produced overall a smaller amount of words than healthy controls and exhibited more difficulties in semantic fluency than phonemic fluency subtests. As suggested by the authors, this could be explained by a decrease in their access to semantic information. Depression has previously been included in investigations on verbal fluency performance in healthy older adults; albeit, to our knowledge, in only one study and as background variable (Bryan et al., 1997). Subclinical depressive symptoms are a common cause of other restrictions in old age (Steffens et al., 2000). For example, current research suggests impaired performance in more demanding and effortful tasks in older adults with subclinical depression (Sedek, Brzezicka, & Von Hecker, 2010) and subclinical depression has been found to moderate the relations between subjective sleep quality and cognitive performance in healthy old age (Sutter, Zöllig, Allemand, & Martin, in press). Therefore, it seems essential to examine subclinical depression as a further background variable in relation to verbal fluency performance.

It must be noted that the findings discussed above mostly derive from either the initial letter fluency or the animal naming subtest. To date, no studies have investigated the effects of background variables on phonemic switching and semantic switching fluency performance and only a few studies have examined performance in excluded letter fluency. Furthermore, there is a lack of empirical data investigating the influence of these background variables on any word production task that exceeds one minute. For example, with longer task duration, the association between age and verbal fluency performance might not be focused on semantic fluency measures. An extended task duration might reinforce the previously revealed tendency of age to affect other verbal fluency measures such as phonemic fluency (albeit to a lesser extent than semantic fluency; Tombaugh et al., 1999), as performance differences might be larger with increasing task duration.

Besides background variables, several cognitive variables are thought to be involved in verbal fluency performance. First, verbal fluency has been found to rely on processing speed, because performance is based on a time limit. Bryan et al. (1997) even suggested that the frequently found age-related differences in verbal fluency performance could be better explained by a decline in processing speed. Second, verbal fluency subtests also reflect participant’s verbal knowledge. The larger the vocabulary, the more words might be produced. Findings of a study by Salthouse, Atkinson, and Berish (2003) suggested that both processing speed and verbal knowledge influence initial letter fluency performance. Third, verbal fluency performance has also been found to require successful retrieval from memory as well as the formulation of effective strategies for encoding and recall (Bryan, Luszcz, & Pointer, 1999). In fact, Bolla et al. (1990) identified a strong association between initial letter fluency and the Rey Auditory Verbal Learning Test.

As verbal fluency is a frequently applied task of executive functions, there are also executive processes that have been discussed in relation to performance on this task. However, the suggested relations with these processes are primarily based on theoretical assumptions rather than observations. To illustrate this, it has been hypothesized that verbal fluency involves shifting. That is, shifting could be required to switch between words within a category or to switch to a different strategy, as soon as there are no more words available (Cauthen, 1978; Sutin et al., 2011). Furthermore, another relevant executive process for verbal fluency performance is inhibition, for example, to suppress repetitions of the same word (Weiss et al., 2003). Although it has been suggested that all verbal fluency subtests involve inhibition to some extent (Henry et al., 2004), inhibition has been attributed in particular to excluded letter fluency (Kemps & Wilsdon, 2010). It was argued that this subtest involves inhibitory processes more extensively, as it requires the generation of words not containing a specified letter (Bryan et al., 1997). Finally, updating or working memory has also been associated with verbal fluency performance. It was hypothesized that working memory is relevant to monitor and update previously-mentioned words, so as to avoid repetitions (Henry & Crawford, 2004).

In this context, it is important to note that the extent to which these cognitive processes might be associated with verbal fluency could also depend on the subtest used. For example, while phonemic fluency entails searching for words based on letters, semantic fluency requires searching within a semantic network (Henry, Crawford, & Phillips, 2005). As has been pointed out previously, deficits in semantic fluency might reflect problems in semantic memory, while deficits in phonemic fluency could be attributed to other cognitive processes, such as verbal knowledge (Bryan et al., 1997). In a recent meta-analysis on verbal fluency performance in patients with focal cortical lesions, Henry and Crawford (2004) found that phonemic and semantic fluency involved executive processes to the same degree. In our view, this may be true for initial letter fluency and animal naming, as the instructions are similar for both subtests (i.e., to produce as many words as possible with a given letter or within a given category). However, other verbal fluency subtests that require switching between letters or categories or inhibiting a specific letter might involve further cognitive processes. Moreover, with respect to the association with cognitive variables and the third minute of word production, no data exist. However, it has been suggested by Elvevåg et al. (2001) that working memory could also be relevant during extended task durations, as monitoring and updating of previously-mentioned words might be increasingly important to avoid repetitions over a task time period.

The present study

The primary aim of the present study was to investigate five different verbal fluency measures in healthy old age. Apart from the most frequently used fluency measures, initial letter fluency and animal naming, we included further subtests, excluded letter fluency, phonemic switching fluency, and semantic switching fluency. Moreover, we prolonged the assessment of verbal fluency to three minutes, which allowed us to compare the first and the third minute of word production. This could provide different information than the frequently utilized assessment of one minute. We expected that these five verbal fluency subtests would differ in the mean quantity of words produced by the participants and that the mean number of words produced in the first minute would be greater than in the third minute. Furthermore, we were interested in associations across these two time conditions, hoping to shed light on the stability of verbal fluency performance between the first and third minute.

As a second aim, we investigated the associations between these five verbal fluency subtests, the two time conditions, and several background and cognitive variables. We used all variables previously found to be associated with either initial letter fluency or animal naming, and further investigated their relations with the less-frequently used tests. As background variables we used age, gender, education, and subclinical depression. Based on previous findings, we hypothesized that, in the first minute of word production, subclinical depression would be significantly related to semantic fluency (i.e., animal naming and semantic switching), age additionally to excluded letter fluency, and education to all verbal fluency measures. No association was expected with gender. With respect to the third minute of word production, we expected that age would be negatively associated with performance on all verbal fluency subtests, as more time would be needed with increasing age to come up with the same quantity of words produced by younger participants. As regards the relations between verbal fluency performance in the first minute and cognitive variables, it was hypothesized that performance on all five subtests would vary between the different cognitive variables, in line with previous suggestions. That is, initial letter fluency and animal naming might involve verbal knowledge and processing speed, while excluded letter fluency might rely on inhibition. On the other hand, phonemic and semantic switching might be related to shifting. For performance in the third minute, we further expected that working memory would be associated with performance on all verbal fluency subtests.

5.1.2 Methods

Participants and procedure

One-hundred older adults (55% women; level of years of education: M = 10.0, SD = 2.4) ranging in age between 64-92 years (M = 72.2, SD = 5.7) participated in the study. Participants were recruited at a lecture for senior citizens at the University of Zurich or through the distribution of flyers in seniors associations. Participants were in good health condition and none reported brain injuries, psycho-affective medication, drug consumption or diseases affecting brain functioning. All participants were native German speakers. The study was approved by the institutional ethics committee and written informed consent was obtained from all participants. They received a personal performance profile and a voucher in the value of 10 CHF (approximately $10). Individual testing took place at the research laboratory of the Department of Psychology at the University of Zurich.

Verbal fluency

Five different measures of verbal fluency were used. Letter fluency was assessed by asking participants to generate as many words as possible starting with the letter S (initial letter fluency) and alternately starting with G and R (phonemic switching). Category fluency was assessed by asking participants to generate as many words as possible of the category of animals (animal naming) and to alternately generate a word of the category sports and a word of the category fruits (semantic switching). Furthermore, excluded letter fluency (Bryan et al., 1997) was used. In this task participants are asked to generate words not containing a specific letter (i.e., the letter e). The variables used for analyses were the number of correct responses produced during the first and the third minute of all five verbal fluency subtests. Additionally, the number of perseverative errors (i.e., the same word repeated) and rule-breaking errors (words that would not appear in a German newspaper or book, words including the same word stem, and proper names) were assessed, however, they were not included in the total verbal fluency score.

Background variables

Participants completed a brief questionnaire assessing sociodemographic information such as age, gender, and years of education. Furthermore, the short-version of the German Geriatric Depression Scale (GDS; Sheikh & Yesavage, 1986) was used to assess subclinical depression. Possible scores range from 0 to 15, and a score of > 6 has previously been suggested to yield the best sensitivity and specificity for clinically significant depression (Gauggel & Birkner, 1999). Accordingly, in the present study participants yielding a score of 6 and higher were excluded from analyses.

Cognitive variables

Additionally, participants were administered the following cognitive tests: Processing speed, verbal knowledge, episodic memory, shifting, inhibition, and working memory.

Processing speed. Processing speed was assessed with the Digit Symbol Substitution Test (Neuropsychological Aging Inventory [NAI]; Oswald & Fleischmann, 2006), which requires participants to assign nine simple symbols to the numbers 1 to 9 during the time of 90 seconds.

Verbal knowledge. A multiple-choice vocabulary test (MWT-B; Lehrl, 1977) was used to assess verbal knowledge. In this test, participants are asked to find one correct word within four meaningless words. The total number of correctly recognized words out of 37 items was used for further analyses.

Episodic memory. Memory was assessed using the Verbal Learning and Memory Test (Verbaler Lern- und Merkfähigkeitstest [VLMT]; Helmstaedter, Lendt, & Lux, 2001). A list of 15 words was read aloud by the experimenter five times. Participants were asked to repeat all the words of the list they could remember across five trials.

Shifting. We used the Trail Making Test (Reitan, 1971) to assess set-shifting. In form A of this test, participants are asked to combine as fast as possible numbers in ascending order. In form B, participants are required to alternately combine numbers and letters (e.g., 1, A, 2, B, 3, C, etc.). The time to complete the task B minus the task A served as the outcome variable (cf. Ble et al., 2005).

Inhibition. To assess inhibition we used the Stroop test (Comalli, Wapner, & Werner, 1962). Participants were asked to read the names of four colors (red, blue, green, and yellow) presented on a test sheet. In the next condition, participants were asked to name red-, blue-, green-, or yellow-colored dots randomly presented on an additional test sheet. In the last condition, participants were asked to identify the color of the ink of a word disregarding reading the word (e.g., the word “green” printed in red ink). In all three conditions, the time to read the names, respectively name the colors correctly was recorded. For the analyses we calculated the difference between the second and the third condition.

Working memory. To assess working memory, we used the computer-based N-back test (Dobbs & Rule, 1989) from the Test Battery for Attentional Performance, TAP 2.1 (Zimmermann & Fimm, 2007). In this test, a sequence of numbers is presented on the screen and participants are required to indicate for each number whether or not it is equal to the penultimate number (i.e., 2-back) by pressing the ‘yes’ or ‘no’ button in front of them. The dependent variable was the mean score of the correct responses.

Statistical analyses

First, to examine if the amount of words produced differed between the verbal fluency subtests, we used paired-sample t-tests. Controlling for multiple comparison we applied Bonferroni’s correction (.05/10 = .005). Furthermore, we compared the difference in the effect size between word productions in the first minute and word productions in the third minute, using Cohen’s d (Morris & DeShon, 2002). Moreover, we applied Pearson correlation to investigate the relations between the two time conditions within each verbal fluency measure. In addition, we tested whether the correlations were different between the five subtests using Steiger’s z.

Second, for the associations between the five verbal fluency subtests and several background variables we correlated age, gender, education, and subclinical depression with each verbal fluency measure. Furthermore, to investigate the relations between cognitive functions and the five verbal fluency measures for both time conditions, we used partial Pearson correlation controlling for the background variables. For all correlations we applied Bonferroni’s correction (background variables: .05/4 = .0125; cognitive variables: .05/6 = .008).

5.1.3 Results

Five verbal fluency measures

Descriptive statistics for each of the five verbal fluency measures are depicted in Table 1. The mean amount of words produced in the first minute was greatest for animal naming and lowest for excluded letter fluency, whereas the mean amount of words in the third minute was also greatest for animal naming but lowest for semantic switching fluency. The pair-wise comparisons of all five verbal fluency tests revealed that the total amount of words differed on all pairs in the first minute as well as the third minute (all $ps < .005$), except for three tests in both time conditions (initial letter vs. phonemic switching; initial letter vs. semantic switching; and phonemic switching vs. semantic switching, all ps > .05).

Furthermore, the difference in the effect size between word productions in the first minute compared to word productions in the third minute was significant for all five verbal fluency subtests. This indicates that within each verbal fluency subtest the number of correctly generated words differed between the two time conditions and was lower for all subtests in the third minute. Moreover, correlations between the first minute and the third minute of each task were significant, indicating medium-sized stability of verbal fluency performance over three minutes. The correlation within phonemic switching fluency was found to be the most stable and the correlation of semantic switching fluency to be the least stable. We performed additional analyses to test whether the correlations were significantly different between the verbal fluency subtests. Results showed that the correlation between the first and the third minute of performance on phonemic switching was significantly different from the correlation between the first and the third minute of semantic switching performance (Steiger's $z = 2.34$; $p < .05$). Similarly, the correlation between the first and the third minute of performance on animal naming was significantly different from the correlation between the first and the third minute of phonemic switching performance (Steiger's $z = -2.08$; $p < .05$).

Table 1. Comparison of five verbal fluency subtests and the first minute and the third minute of word production

	Minute 1 M (SD)	Minute 3 M (SD)	d	Decrease of performance in %	r_{1-3}
a) Initial letter	11.88 (4.20)	6.11 (3.42)	1.44***	49	.45***
b) Animal naming	18.67 (4.93)	9.86 (4.07)	1.64***	48	.29**
c) Excluded letter	10.28 (3.74)	7.27 (2.82)	.085***	30	.41***
d) Phonemic switching	12.33 (3.77)	6.34 (2.94)	1.83***	49	.52***
e) Semantic switching	12.40 (3.07)	5.82 (2.15)	2.07***	54	.26**

Note. d = Cohen's d, the difference between the mean of the first minute and the mean of the third minute divided by the pooled standard deviation (Morris and DeShon, 2002). r_{1-3} = correlation between the first minute and the third minute of word production. Phonemic fluency measures: initial letter, excluded letter, and phonemic switching; semantic fluency measures: animal naming and semantic switching.

Background variables

Results of the background variables are depicted in Table 2. Comparing age and performance on all five verbal fluency subtests revealed a significant finding for animal naming and excluded letter fluency, in both the first and the third minute of word production (animal naming rs = -.35; -.26; excluded letter rs = -.27; -.27). Furthermore, age was negatively related to performance in the first minute of semantic switching and the third minute of initial letter fluency (rs = -.27; -.36). However, no significant relation of age and phonemic switching performance was found. Regarding gender, no significant result on any verbal fluency measure was obtained. In contrast, education positively correlated with phonemic switching performance in the first minute and initial letter fluency performance in the third minute (r = .27; r = .32). Regarding subclinical depression, the only significant relations was found for the first minute of semantic switching fluency (r = -.27), however, barely significant at the .0125 level (p = .011).

Table 2. Correlations between background variables and the five verbal fluency subtests in the first minute and the third minute of word production

	Initial letter		Animal naming		Excluded letter		Phonemic switching		Semantic switching	
	1	3	1	3	1	3	1	3	1	3
Age	-.01	**-.27**†**	**-.35***†**	**-.26**†**	**-.27**†**	**-.27**†**	-.12	-.07	**-.36***†**	-.15
Gender	-.14	.03	-.03	-.06	-.14	-.20*	-.10	-.14	.05	-.12
Education	.21*	**.27**†**	-.07	.25*	.21*	.03	**.32***†**	.16	.25*	-.09
Subclinical depression	-.13	-.16	-.10	-.11	-.02	-.23*	-.15	-.13	**-.26*†**	-.10

Note. N = 94; *p < .05, **p < .01, ***p < .001, †Bonferroni correction .05/4= .0125.

Cognitive functions

Results are depicted in Table 3. Initial letter fluency positively correlated with processing speed in both the first and the third minute. Besides processing speed, phonemic switching fluency also positively correlated with episodic memory and negatively correlated with shifting in the first and the third minute, as well. These results indicate that both phonemic variants of verbal fluency show stability in the associations with cognitive functions across both time conditions. On the other hand, semantic switching fluency performance also correlated with processing speed and shifting in the first minute. For the third minute, however, no significant correlation was found. Performance on animal naming positively correlated with verbal knowledge and episodic memory in the first minute and episodic memory and shifting in the third minute. Finally performance on excluded letter fluency revealed a positive correlation with processing speed in the first minute and episodic memory and inhibition in the third minute, indicating that there was a shift of associated cognitive variables from the first to the third minute.

Table 3. Correlations between cognitive variables and verbal fluency subtests comparing the first minute and the third minute of word production, controlling for demographic variables and subclinical depression

	Initial letter		Animal naming		Excluded letter		Phonemic switching		Semantic switching	
	1	3	1	3	1	3	1	3	1	3
Processing speed	**.45***†**	**.34***†**	.26*	.25*	**.39***†**	.22*	**.37***†**	**.34***†**	**.32***†**	.16
Verbal knowledge	.07	.19	**.33**†**	.01	.11	.20	.25*	.16	.14	.09
Episodic memory	.19	.17	**.28**†**	**.28**†**	.21*	**.28**†**	**.30**†**	**.27**†**	.19	.19
Shifting	-.21*	-.15	-.14	**-.31**†**	-.25*	-.09	**-.32**†**	**-.29**†**	**-.35***†**	-.21*
Inhibition	-.14	-.20	-.07	-.12	-.21*	**-.29**†**	-.10	-.21*	-.16	-.09
Working memory	.16	.14	.07	.01	.24*	-.07	.14	.13	.20	.12

Note. N = 94; *p < .05, **p < .01, ***p < .001, †Bonferroni correction (05/6 = .008).

5.1.4 Discussion

The aim of the present study was to investigate performance on different verbal fluency subtests in healthy old adults. Moreover, this study combined several variables previously associated with verbal fluency performance and examined differences in their relations to the different verbal fluency subtests and the two time conditions (i.e., background variables and cognitive variables).

We found that the total amount of correctly produced words significantly differed between the verbal fluency subtests compared in the first and the third minute, except for three comparisons. That is, on initial letter, phonemic and semantic switching fluency, a similar amount of words was produced. Moreover, we found a significant difference between word productions in the first minute compared to word production in the third minute in all five verbal fluency subtests, indicating that participants were susceptible to a decline in performance induced by longer task duration. Importantly, the correlations between performance during the first minute and the third minute were significant on all subtests, which indicate that participants producing a large number of words in the first minute also produced a large number of words in the third minute. However, this measure of stability was significantly different between semantic and phonemic fluency (i.e. animal naming and semantic switching compared to phonemic switching fluency), with a greater stability for phonemic fluency. Hence, this study extents previous research by showing differences in phonemic and semantic fluency performance in healthy old age and furthermore demonstrating the stability of performance over three minutes word production.

Several background variables were differently related with performance on the five verbal fluency measures. Consistent with previous findings for the first minute of word production (Bryan et al., 1997; Tombaugh et al., 1999), we found that age was associated with semantic fluency (animal naming and semantic switching fluency) as well as excluded letter fluency in our sample of healthy older adults. No association of age and two phonemic fluency subtests, initial letter and phonemic switching fluency, was found for word production in this time condition. Our study expands previous research by showing that this pattern of age being associated with semantic fluency also holds for switching fluency measures. Age seems to play a more important role for semantic than phonemic fluency, irrespective of the task involving switching between items or not. However, this study is the first to demonstrate an association of age and verbal fluency measures with extended task duration. More precisely, age was additionally related to initial letter fluency performance in the third minute.

This contradicts the above mentioned current assumptions and indicates that with increasing task duration age seems to be associated with verbal fluency performance in general.

Our results further revealed that education was associated with performance on two phonemic fluency measures, that is initial letter fluency and phonemic switching fluency. However, correlational analyses were adjusted using Bonferroni’s correction. At a less strict level, we would find that education is associated with all five verbal fluency measures which reflects the findings currently available on initial letter fluency and animal naming across the lifespan (Kempler et al., 1998; Shores et al., 2006; Tombaugh et al., 1999). Therefore we would not assume a stronger relation between education and phonemic fluency; instead education seems in general associated with verbal fluency performance. Highly educated older adults might use a larger vocabulary and also have more different strategies available to generate new words which would not solely impact a specific verbal fluency subtest.

Controlling for the background variables, the relation of several cognitive variables and verbal fluency performance revealed some interesting findings. Our results suggest that the only cognitive variable associated with initial letter fluency performance in the first as well as the third minute was processing speed. For this subtest, the strategy to produce as many words as possible with emphasis on processing speed seems the most effective. Also, there is no additionally instruction as for example to switch to or to inhibit a specific word which could explain why no other cognitive process was involved. However, a different picture emerged for the same subtest requiring semantic processing. Animal naming was found to be associated with verbal knowledge, episodic memory, and shifting. While memory was associated with performance in both time conditions, verbal knowledge was only related to performance in the first minute and shifting to performance in the third minute. Memory in animal naming could be explained by the fact that in this task the highest amount of words was generated (first minute $M = 18.67$; third minute, $M = 9.86$), which could require a higher memory load to not repeat the same words. The association with shifting might indicate that with increasing testing time shifting between different clusters of animal categories is necessary in order to switch to other subcategories of animals and thus avoiding repetitions. This relates to the finding of Troyer, Moscovitch, and Winocur (1997) stating that switching, besides clustering, is required for successful verbal fluency performance. Hence, in contrast to a previous assumption that both initial letter and animal naming might involve executive functions to the same degree (Henry & Crawford, 2004), our findings suggest that these most frequently used subtests of verbal fluency differ in the cognitive processes associated with performance.

Performance on excluded letter fluency was associated with processing speed in the first minute and episodic memory and inhibition in the third minute. This shift of cognitive processes across the two time conditions seems functional as the decrease in percent from the first to the third minute was found to be the smallest in all subtests. Performance on excluded letter fluency was the only measure associated with inhibition. This finding is at odds with the view of other researchers suggesting that inhibition is required for verbal fluency performance in general (Perret, 1974; Weiss et al., 2003). Although in all verbal fluency subtests it is important to avoid errors, our findings indicate that only the subtest to generate words that do not contain a specific letter noticeably relies more heavily on inhibitory processes and this is only the case in the third minute when task demand might be increased.

Phonemic switching was found to be related to processing speed, episodic memory, and shifting, in both time conditions. The relation to shifting is not surprising given that the task demands shifting between two initial letters. Furthermore, the association with memory could be explained by the fact that participants need to remember to which letter they are required to shift to. Also, for the first minute of word production on semantic switching fluency the findings were relatively similar, as processing speed and shifting are also found to be involved. For the third minute, however, no relation to any cognitive process was found. This is interesting given that also no background variable was related to performance on this subtest. Furthermore, of all the verbal fluency measures the lowest correlation between the first and the third minute of word production was found on semantic switching fluency. Further research is needed to investigate variables associated with successful performance on this task.

Surprisingly, no significant relation was found between working memory and verbal fluency performance. In addition, verbal knowledge was only associated with performance in animal naming. This finding contradicts the results reported by Unsworth, Spillers, and Brewer (2011) who studied several cognitive processes associated with verbal fluency performance in young adults. They found that working memory as well as verbal knowledge was significantly related to a composite fluency measure including two semantic and two initial letter fluency subtests. However, these discrepant finding could be due to the fact that we controlled for several background variables.

There are theoretical implications with practical consequences for the use of verbal fluency subtests. There is evidence for different relations among all verbal fluency subtests and several cognitive variables. This suggests that different cognitive processes are underlying successful performance of these tasks. Future studies are needed that assess cognitive processes with different measures to conclude on the relations with verbal fluency subtests. Moreover, the present findings have several practical implications. First, for the assessment of phonemic fluency (i.e., initial letter and phonemic switching fluency) a one minute assessment time might be sufficient, as there was no additional information obtained from the third minute of word production regarding most background and cognitive variables. This was also reflected in the correlation between the two time conditions of both subtests, which were the highest across all five verbal fluency measures. Unless there is interest in age differences, then we would suggest assessing initial letter fluency with a longer task duration because we found a negative relation with age in the third minute of word production. Second, as regards the remaining three verbal fluency measures (i.e., animal naming, excluded letter, and semantic switching fluency) there was a difference in verbal fluency performance and several variables assessed in the first and the third minute of word production. Therefore, it may be worthwhile considering different task durations for these subtests, as we found that each of these subtests embedded different information.

In conclusion, for the assessment of verbal fluency, different subtests exist. However, depending on the subtest and the task duration used, different cognitive variables and to some extent different background variables appear to be related to performance. For example, comparing performance on initial letter, phonemic and semantic switching fluency, there was no difference in the mean amount of words produced during the first as well as the third minute. However, performance differed especially on the cognitive processes involved. Hence, the extent to which these verbal fluency measures differ in their relation to other variables should be considered when using verbal fluency, for example, in clinical settings.

5.2 Study 2: Plasticity of verbal fluency in older adults: A 90 minutes telephone-based intervention[3]

5.2.1 Introduction

Verbal fluency is a popular neuropsychological test in which participants are typically asked to generate as many words as possible from a specific semantic or phonemic category (i.e., "animals" or "words that start with a designated letter; Kempler et al., 1998). The task has high diagnostic utility (Kempler et al., 1998; Monsch et al., 1992) and is frequently used in cognitive aging research (Fisk & Sharp, 2004). As older adults commonly report word finding difficulties (Wierenga et al., 2008), verbal fluency is often used to examine access to phonemic and semantic information under the condition of time constraints (Monsch et al., 1992). There is consensus that verbal fluency is highly age sensitive (Hultsch et al., 1992; Kempler et al., 1998; Tombaugh et al., 1999; Troyer et al., 1997). Therefore, the aim of the present study was to develop an intervention to improve verbal fluency performance in healthy older adults.

A decline in verbal fluency performance with advancing age has been reported for both, phonemic and semantic fluency. Although some studies suggested that semantic fluency is generally more affected by age (Brickman et al., 2005; Tombaugh et al., 1999), there is also evidence for age-related differences in phonemic fluency. For example, an age-related decrease in performance has been observed for initial letter fluency (Phillips, 1999) and excluded letter fluency (Bryan et al., 1997). This age-related reduction in verbal fluency performance could be associated with several cognitive processes that are required for successful verbal fluency performance and for which an age-related decrease has been reported. The following processes have been suggested as important for verbal fluency performance (Rosen & Engle, 1997): Monitoring, inhibition of previously recalled words, and self-generation of cues to produce new words. Other cognitive variables discussed are processing speed (Salthouse, 1993), switching between two mental sets (Troyer et al., 1997), and retrieval from long-term memory and short-term memory (Ruff, Light, Parker, & Levin, 1997). All of these cognitive processes could explain age-related differences in verbal fluency task performance. However, the extent to which these processes are associated with verbal fluency performance in healthy older adults also depends on the verbal fluency task used.

[3] A similar version of this chapter has been accepted for publication in “Gerontology” (Sutter, Zöllig, & Martin, in press).

Examining three subtests of phonemic fluency more closely, there are three processes that have been linked to each subtest. As an illustration, the subtest initial letter fluency requires generating as many words as possible within a time limit. For this task, processing speed accounts for age-related differences in performance (Phillips, 1999). This is in accord with the processing speed theory stating that with increasing age a decrease in processing speed leads to age-related differences in cognitive functions (Salthouse, 1996). In fact, older adults produce fewer words in initial letter fluency compared to younger adults and processing speed mediates this age effect (Salthouse, 1993). In contrast, the subtest excluded letter fluency which requires to produce words not involving a designated letter has been suggested to require inhibitory processes (Kemps & Wilsdon, 2010) which show an age-related decline (Hasher et al., 1991). Finally, the subtest phonemic switching fluency in which participants are required to switch between two given initial letters involves shifting between two mental sets or categories and is frequently used as a variant of task-switching (Wecker, Kramer, Hallam, & Delis, 2005) which shows age-related performance declines (Kray & Lindenberger, 2000). Consequently, these three subtests of phonemic fluency involve different underlying processes which, in turn, have also been found to be age-sensitive. It must be noted, however, that each of these three cognitive processes is not exclusively associated with one of the three verbal fluency subtests, as all of these subtests impose demands on processing speed, shifting and inhibition, albeit not to the same extent.

Based on these relations, the present study concentrates on how to improve verbal fluency performance in healthy older adults. By using the three variants of verbal fluency (initial letter fluency, excluded letter fluency, and phonemic switching fluency), we target the different underlying cognitive processes discussed (i.e., processing speed, shifting, and inhibition). Thus, with this intervention, we examined the extent to which verbal fluency is modifiable in a short-term intervention and in which verbal fluency task and its underlying core process the largest effects can be achieved.

More specifically, we aimed at investigating whether (1) we find training gains in all three training tasks and whether these training gains differ across the three training groups, (2) we find transfer effects to other verbal fluency tasks and (3) we find transfer effects to untrained tasks. Accordingly, on the continuum of transfer effects, we studied transfer with tasks that are similar to the trained task and differ only in specific items (i.e., other verbal fluency tasks), and with untrained tasks that are dissimilar. For these untrained tasks and for all three training groups, we predicted training-specific improvements in tasks that involve the same underlying processes as the trained task. That is, for the group receiving training in initial letter fluency and, thus, processing speed, we predicted improvements in a processing speed task. For the phonemic switching fluency training group, we predicted performance improvements in a task-switching task. Finally, for the excluded letter fluency training group, we predicted performance improvements in an inhibition task. In addition to the transfer tasks targeting these cognitive functions, we further included measures of short-term memory, long-term memory, and working memory, as all three aspects of memory have been found to be associated with general verbal fluency performance (Rosen & Engle, 1997; Ruff et al., 1997). The training and transfer tasks are depicted in Figure 3.

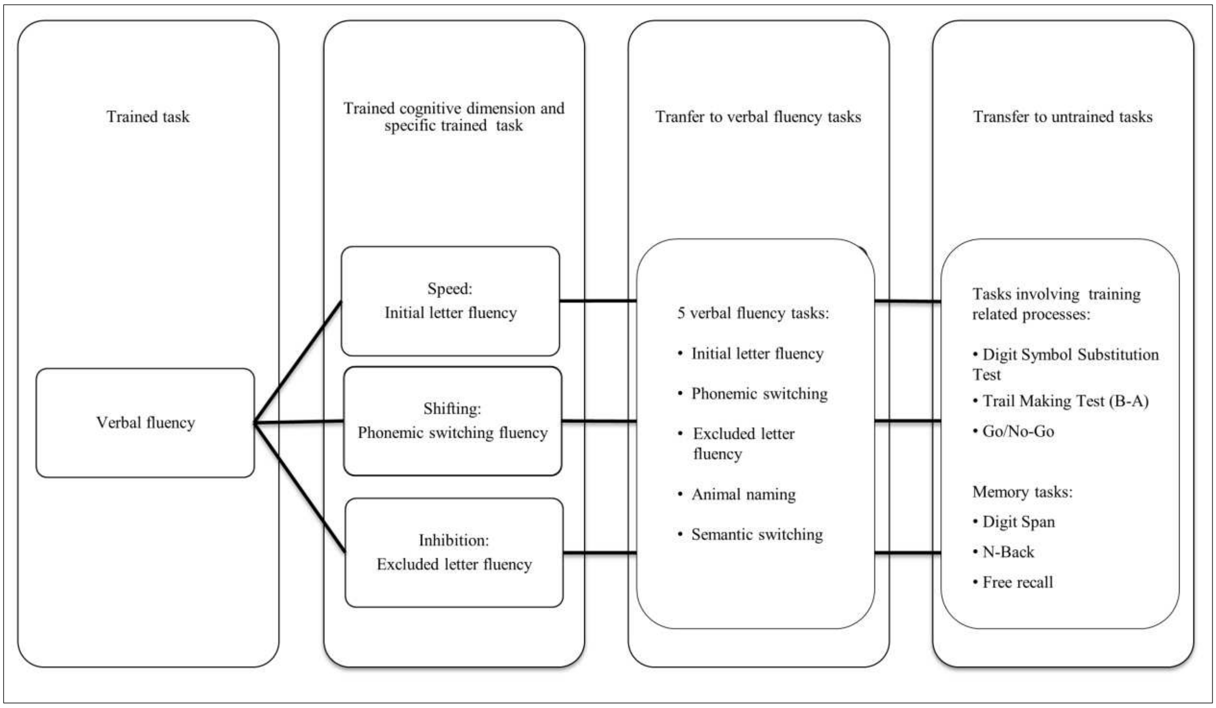

Figure 3. Conceptual model of the training intervention for the three training groups.

Verbal fluency does not require writing or working on the computer by the participants. Therefore, verbal fluency lends itself very well to be assessed by telephone. Consequently, the training was carried out by telephone, requiring six minutes per daily session and, thus, resulting in a total training time of 90 minutes. Because this one-to-one training over the telephone had a strong social component, we further evaluated if improvements are specific to the training interventions or if similar improvements can be achieved in a social contact group without a specific training intervention. In addition to a no-contact control group, an active control group was included. The engagement task of our active control group is comparable to the tasks used in the intervention study by Goh and Park (2009) in which older adults were randomly assigned to different conditions of engagement (i.e., quilting versus digital photography plus social activities). Thus, we compared performance gains of the different training groups with an active control group and a no-contact control group.

To sum up, we wanted to examine if a specific short-term cognitive intervention could lead to significant improvements in cognitive functioning, if the effects vary between different subtests of the training tasks, and if there is a transfer to untrained tasks. If the effectiveness of such a short-term intervention can be demonstrated, the results would provide the basis for cognitive interventions in old age that could be both ability-specific and possible to integrate into the lifestyle of aging adults.

5.2.2 Methods

Participants

Participants were 105 older adults (M = 72.3; SD = 5.7; range = 64 - 92 years). Eighty-four participants were randomly assigned to one of three training groups or an active control group, and 21 participants were assigned to a no-contact control group (Figure 4). The participants were recruited at a lecture for senior citizens at the University of Zurich and through the distribution of flyers. All participants were native German speakers. The study was approved by the institutional ethics committee. Written informed consent was obtained from all participants and they received CHF 10 (approx. 11 USD) for their participation. Three participants dropped out during data collection because of their inability to complete the training and one was excluded from data analysis due to incomplete responses; therefore, the analyses are based on the data of 101 participants.

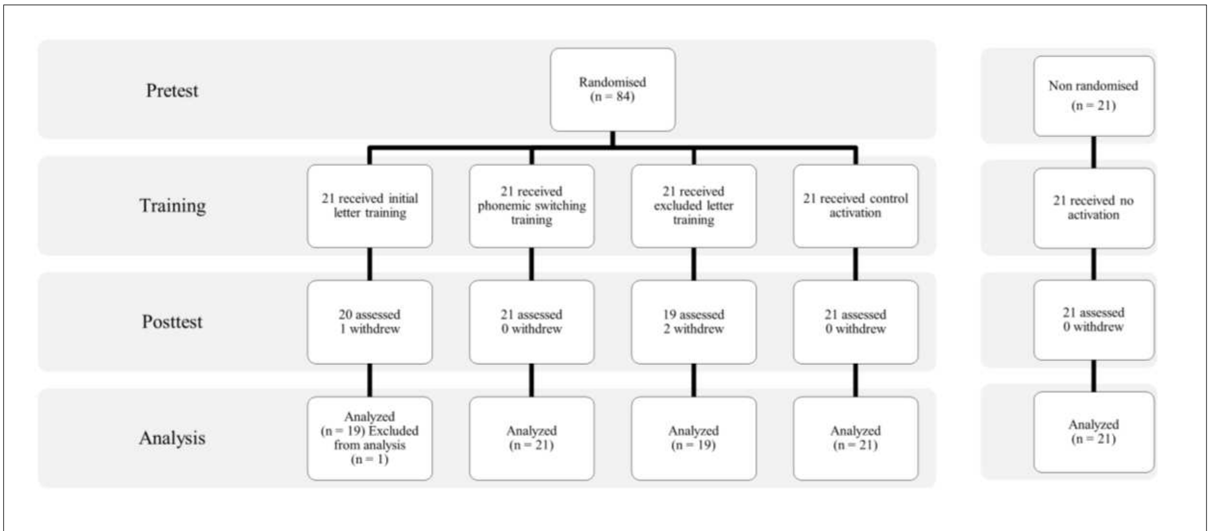

Figure 4. Flow diagram of the progress through the phases of randomized trial.

Procedure and interventions

We invited participants to the laboratory for a pretesting session in which baseline performance on a battery of cognitive tests was assessed. Individual testing lasted about two hours. Training interventions and control activity were carried out via telephone and required 15 sessions, each session lasting six minutes. Participants of the three training groups worked on two verbal fluency tasks in each session. To assess training gains throughout the training, the same letters were repeated in the training sessions 1, 6, and 11. In order to complete the three weeks of training and to maximize transfer effects, training sessions continued until session 15. Some basic rules had to be observed by all three training groups, that is, no proper names, no words including the same word stem, and only words that would appear in a German newspaper or book were allowed. Furthermore, it was emphasized that participants should avoid perseverations. The three training interventions were based on phonemic fluency tasks, because we were interested in targeting specific cognitive processes that have been linked to different variants of phonemic fluency. We refrained from including semantic fluency into the training protocol. Participants of the active control group followed the same schedule as the three training groups (see Table 4). To analyze the improvements after training, a posttesting session with the identical tests from the pretesting session was carried out. Participants were assigned to the following groups:

Initial letter fluency training group (A). Participants were asked to generate as many words as possible with a given initial letter (e.g., “P”) within three minutes.

Phonemic switching fluency training group (B). Participants were asked to alternate between two given initial letters (e.g., “H” and “T”) within three minutes. The importance of switching between the two letters was emphasized in the instruction.

Excluded letter fluency training group (C). Participants were asked to generate words without a given letter (e.g., words without the letter “n”) within three minutes. The instruction emphasized the importance of not committing errors and of inhibiting false reactions.

Active control group (D). Participants were asked about their opinion, thoughts and experiences on a given topic (e.g., “movies” or “traveling”) for the same amount of time. Although this group underwent general activation, this activity was not intended to improve a specific cognitive process.

No-contact control group (E). The no-contact control group was invited to the pre- and posttesting session but did not receive any training or further social contact.

Table 4. Training schedule

	Initial letter fluency training (A)		Phonemic switching fluency training (B)		Excluded letter fluency training (C)		Control activity (D)
	Task 1	Task 2	Task 1	Task 2	Task 1	Task 2	Task 1
Session 1	**P**	D	**H-T**	P-D	**n**	i	Movies
Session 2	A	V	M-L	B-A	g	p	Books
Session 3	H	Z	E-F	U-N	b	f	Traveling
Session 4	B	J	K-L	I-U	k	r	Mountains
Session 5	M	O	A-M	T-O	m	s	Leisure
Session 6	**P**	E	**H-T**	K-P	**n**	u	Favorite dish
Session 7	U	F	A-I	D-O	l	a	Seasons
Session 8	K	D	F-N	U-B	h	t	Commercials
Session 9	T	I	M-E	Z-L	o	g	Family
Session 10	H	B	D-K	N-I	d	i	Animals
Session 11	**P**	M	**H-T**	A-Z	**n**	k	Job
Session 12	L	E	M-P	E-D	s	t	Wishes
Session 13	W	F	L-M;	U-I	u	a	Politics
Session 14	N	T	F-K	E-P	p	l	Art
Session 15	I	A	B-A	L-O	f	h	Role models

Note. Task 1 of Session 1, 6, and 11 were used to analyze training gains.

Cognitive assessment

All participants were required to perform a battery of cognitive tests including paper-pencil as well as computerized tests. Training-related transfer effects were examined with other verbal fluency tasks and untrained tasks.

Transfer to other verbal fluency tasks. To assess transfer, four subtests of a German word fluency test (Regensburg Word Fluency Test; Aschenbrenner et al., 2000) were used. Letter fluency was assessed by asking participants to generate as many words as possible, beginning with the letter S (initial letter fluency), and alternately starting with G and R (phonemic switching). Category fluency was assessed by asking participants to generate as many words as possible of the semantic category of animals (animal naming), and alternately between sports and fruits (semantic switching). Furthermore, excluded letter fluency (Bryan et al., 1997) was used in the testing session. This task requires participants to generate words not containing a specific letter (i.e., the letter e). The outcome measure of all five verbal fluency tasks was the number of correct responses produced during three minutes. In addition to the total number of correct responses, the number of perseverative errors (i.e., the same word repeated) and rule-breaking errors (words that would not appear in a German newspaper or book, words including the same word stem, and proper names) were not included in the total verbal fluency score.

Transfer to untrained tasks. To assess transfer to untrained tasks, performance on six different cognitive measures was assessed for all five groups.

Processing speed. To investigate transfer to a task of processing speed, the Digit Symbol Substitution Test of the Nuremberg Aging Inventory (NAI; Oswald & Fleischmann, 2006) was used. The test is intended to assess the general cognitive slowing in old age (Salthouse, 1996) by assigning nine simple symbols to the numbers 1 to 9 during 90 seconds. The outcome measure was the total score of the items correctly assigned.

Shifting. We used the Trail Making Test (Reitan, 1971) to assess transfer to a shifting task. In form A of this test, participants are asked to connect numbers in ascending order (e.g., 1, 2, 3, etc.). Form B requires to alternately connect numbers and letters in ascending order (e.g., 1, A, 2, B, 3, C, etc.). The time to complete part B minus the time to complete part A was used for further analyses.

Inhibition. To assess transfer to an inhibition task, a computerized testing version of the Go/No-Go task, implemented with the Tests of Attentional Performance (TAP, version 2.1; Zimmermann & Fimm, 2007), was used. This subtest assesses the ability to suppress a reaction triggered by external stimuli in favor of an internally controlled behavior. The participants are required to respond as quickly as possible to an appropriate target (i.e., a horizontal cross), while controlling an inappropriate impulse (i.e., not to respond to the fixed cross). Performance in this task was assessed as the mean of correct answers.

Short-term memory. To assess short-term memory, the Digit Span Forward and Backward task was used. In these tests, also adapted from the NAI (Oswald & Fleischmann, 2006), participants are required to repeat the digits in the same order (i.e., forward) or in reversed order (i.e., backward) as verbally presented by the experimenter. The total digit span (forward plus backward) was used for analysis.

Working memory. To assess working memory, we used the N-back test (Dobbs & Rule, 1989) from the Tests of Attentional Performance (Zimmermann & Fimm, 2007). A sequence of numbers is presented on a screen one after the other and participants are required to indicate for each number whether or not it is equal to the penultimate number (i.e., 2-back) by pressing the ‘yes’ or ‘no’ button in front of them. The dependent variable was the mean score of the correct responses.

Long-term memory. Long-term episodic memory free-recall was assessed using the Verbal Learning and Memory Test (Verbaler Lern- und Merkfähigkeitstest [VLMT]; Helmstaedter et al., 2001), an adapted German version of the Rey Auditory Verbal Learning Test (Rey, 1958, 1964). The participants were asked to repeat all the words of a previously learned list consisting of 15 words which were read to them one at a time at a pace of one word per second. The words were repeated on five consecutive trials. Recall was tested after a 20-minutes delay. We included this measure of delayed recall in our analyses.

Negative emotional questionnaires. Two questionnaires were used to assess negative emotions. The short-version of the German Geriatric Depression Scale (GDS; Sheikh & Yesavage, 1986) was used to assess depressive symptoms and the state scale of the State-Trait Anxiety Inventory (STAI; Laux, Glanzmann, Schffner, & Spielberger, 1981) was used to assess participants' anxiety. On a 4 point-scale (1= not at all, 2 = a little, 3 = quite, 4 = very much) participants indicated how they were feeling during the testing sessions (e.g., “I am calm”).

Data analysis

Prior to analysis, we tested all variables for normal distribution with the Shapiro-Wilk’s test. To test for differences between the five groups in demographic characteristics as well as baseline performance, we applied one-way analyses of variances (ANOVAs). To evaluate the effects of training, we applied repeated-measures ANOVA including the training sessions 1, 6, and 11. In addition, planned comparisons on the three training sessions were carried out.

To measure transfer effects to verbal fluency tasks and untrained tasks, only training groups that showed training gains were included in the analysis. We applied repeated-measures ANOVA with the performance measures at pre- and posttesting session as dependent variables. To interpret the training improvements between the different groups, we chose the interaction terms (i.e., group x time). To disentangle significant interactions, four contrasts were specified: 1) any activity (i.e., verbal fluency training groups and the active control group) versus no activity (A, B, D vs. E), 2) verbal fluency training versus control activity (A, B vs. D), 3) each verbal fluency training versus control activity (A vs. D, B vs. D), and 4) verbal fluency trainings compared to each other (A vs. B). Excluded letter fluency

(C) training was excluded from contrast analyses due to non-significant training improvements.

5.2.3 Results

Baseline data

Participants of the three training groups and the two control groups did not differ significantly with respect to age, years of education, depression, or state anxiety at pre- and posttest (see Table 5). In addition, there were no significant differences between the five groups in the baseline measures of all cognitive measures at pretest ($p < .01$), except for performance on the Digit Symbol Substitution Test (phonemic switching training group vs. active control group, B vs. D, $p < .05$, with the latter showing a better performance). Therefore, this test was included as a covariate for analyses on the transfer tasks.

Table 5. Mean subject characteristics

	Initial letter fluency training (A)	Phonemic switching fluency training (B)	Excluded letter fluency training (C)	Active control (D)	No-contact control (E)	Overall	p-value
Age	72.45 (4.81)	73.52 (7.00)	72.00 (5.24)	72.57 (5.66)	70.81 (5.42)	72.27 (5.66)	.643
Years of education	10.21 (3.26)	10.19 (2.89)	9.66 (1.75)	9.90 (2.26)	10.14 (1.80)	10.02 (2.42)	.948
Gender (in percent)							.133
Male	47.4	38.1	52.6	23.8	38.1	44.6	
Female	52.6	61.9	47.4	76.2	61.9	55.4	
GDS score							
pre	1.37 (1.30)	1.29 (1.71)	1.95 (1.78)	1.55 (1.72)	0.93 (1.21)	1.41 (1.56)	.342
post	2.00 (4.45)	1.92 (1.93)	0.93 (1.54)	1.12 (1.82)	0.81 (1.12)	1.33 (2.42)	.373
STAI-state score							
pre	28.84 (6.59)	30.52 (6.92)	32.68 (8.83)	32.76 (8.67)	30.67 (7.43)	31.11 (7.72)	.473
post	28.79 7.66)	30.68 (6.82)	28.57 (4.79)	32.67 (9.69)	29.29 (6.19)	30.01 (7.24)	.338

Note. Standard errors are in parentheses. The p-values refer to the comparison of all five groups. GDS = Geriatric Depression Scale. STAI = State Trait Anxiety Inventory.

Training gains

Analyses revealed a significant main effect of time for the group receiving initial letter fluency training (A), $F(2, 36) = 38.83$, $p < .001$, $\eta^2 = .68$, indicating that participants improved performance during training. Contrasts revealed that performance increased from session one to session six, $F(1, 18) = 29.27$, $p < .001$, $\eta^2 = .62$, and from session six to session eleven $F(1, 18) = 15.09$, $p = .001$, $\eta^2 = .46$. Furthermore, a significant main effect of time was found for the group receiving phonemic switching training (B), $F(2, 40) = 49.348$, $p < .001$, $\eta^2 = .71$. Again, contrasts revealed that performance increased from session one to session six, $F(1, 20) = 36.43$, $p < .001$, $\eta^2 = .65$, and from session six to session eleven $F(1, 20) = 24.59$, $p < .001$, $\eta^2 = .55$. Participants of the group receiving excluded letter fluency training (C) did not improve from session one to session eleven, $F(2, 36) = 1.94$, $p = .159$, $\eta^2 = .10$, indicating that this group did not benefit from the three weeks of training. Means and standard errors are presented in Figure 5.

Consequently, there was a significant effect of training on the level of training gain, $F(2, 56) = 11.01$, $p < .001$, $\eta^2 = .28$. Whereas training gains of both, initial letter fluency and phonemic switching fluency training were significantly different from training gains of excluded letter fluency training (Bonferroni: initial letter vs. excluded letter, $p < .001$, phonemic switching vs. excluded letter, $p = .001$), training gains of initial letter fluency training were not significantly different from training gains of phonemic switching training (Bonferroni's post-hoc test: initial letter vs. phonemic switching, $p = 1.000$).

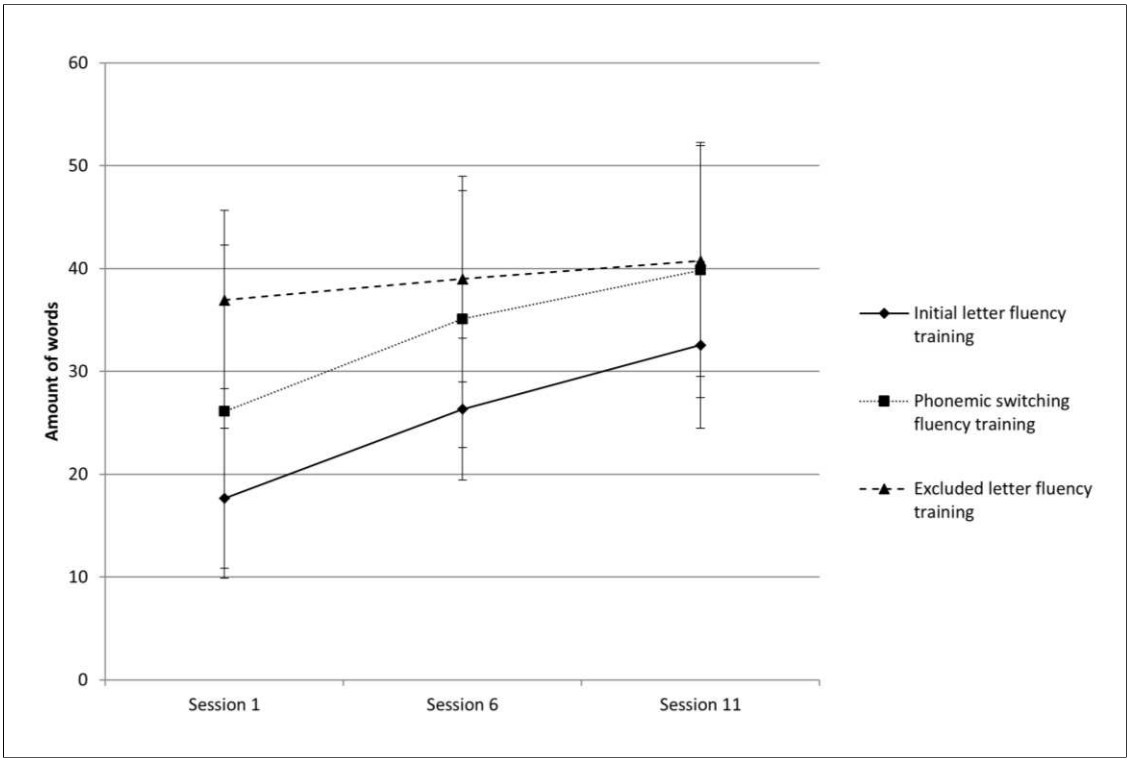

Figure 5. Training gains of the three verbal fluency training groups.

Transfer to other verbal fluency tasks

Because participants of the group receiving excluded letter fluency training did not show significant performance improvement during training, we did not consider this group for further analyses of transfer effects. Therefore, a 4 x 2 repeated-measures ANOVA with group as between-subjects factor and time (pretest, posttest) as within-subject factor was conducted to assess whether the groups differed in the five verbal fluency tasks used (see Table 6). In all tasks except for the excluded letter fluency task, the group x time interactions were significant (phonemic switching fluency, $p < .001$, initial letter fluency, $p =.001$; animal naming, $p = .038$

and semantic switching fluency, $p = .022$), indicating that the change in performance from pretest to posttest was different between groups.

Of the four contrasts specified (see also Table 6), we first compared any activity including the active control group to no activity (A, B, D vs. E; contrast 1). Results revealed that the change over time was significantly smaller for the no-contact control group compared to the average change in all other groups in the following tests: initial letter fluency ($t = 2.71$, $p = .008$, $\eta^2 = .09$), animal naming ($t = 2.60$, $p = .011$, $\eta^2 = .08$.), and phonemic switching fluency ($t = 3.26$, $p = .002$, $\eta^2 = .12$). This indicates that verbal fluency training or social contact significantly increased performance on these tasks compared to having no contact between the pre- and posttest. No significant finding emerged comparing the training groups including the active control group versus the no-contact control group on the semantic switching fluency tasks.

Furthermore, we compared the two training groups versus the active control group (A, B vs. D; contrast 2). This contrast was significant for the initial letter fluency task ($t = 2.86$, $p = .005$, $\eta^2 = .09$) and phonemic switching fluency task ($t = 2.42$, $p = .018$, $\eta^2 = .07$), indicating that the change in performance over time in the active control group was significantly lower than the average change in performance seen in the two verbal fluency training groups. However, for the semantic fluency task, findings were reversed. On this task, the active control group performed better than the two training groups ($t = 2.72$, $p = .008$, $\eta^2 = .09$).

In addition, comparing performance after initial letter fluency training with performance after control activity (A vs. D; contrast 3a), revealed a significant finding on initial letter fluency ($t = 2.69$, $p = .009$, $\eta^2 = .08$) and on semantic switching fluency ($t = 2.99$, $p = .004$, $\eta^2 = .10$). While on initial letter fluency the group receiving initial letter fluency was found to perform better, on the semantic switching fluency task it was the control activity group that outperformed the fluency training group. Comparing performance after phonemic switching training with performance after control activity (B vs. D; contrast 3b) revealed a significant finding on initial letter fluency ($t = 2.25$, $p = .027$, $\eta^2 = .06$), and phonemic switching fluency ($t = 3.64$, $p < .001$, $\eta 2 = .14$), indicating that the participants of the phonemic switching training group performed significantly better on both tasks compared to the active control group.

Finally, we compared performance on each verbal fluency task after initial letter fluency training with performance after phonemic switching training (A vs. B; contrast 4). Results revealed a significant difference between the two groups on phonemic switching fluency ($t = 2.98$, $p = .004$, $\eta^2 = .10$), indicating that the phonemic switching fluency training further increased performance score on this task compared to the initial letter fluency training. No significant difference was found on the remaining four verbal fluency tasks.

Table 6. Mean test scores on verbal fluency tasks

	Initial letter fluency training (A) M(SD)		Phonemic switching fluency training (B) M(SD)		Active control (D) M(SD)		No-contact control (E) M(SD)		p-value (η^2)	Contrast 1 (A, B, D vs. E) p-value (η^2)	Contrast 2 (A, B vs. D) p-value (η^2)	Contrast 3a (A vs. D) p-value (η^2)	Contrast 3b (B vs. D) p-value (η^2)	Contras 4 (A vs. B) p-value (η^2)
	Pre	Post	Pre	Post	Pre	Post	Pre	Post						
Initial letter	23.84 (8.44)	37.47 (11.78)	26.29 (8.02)	38.52 (14.42)	26.29 (12.26)	32.38 (12.21)	25.90 (7.96)	30.47 (10.54)	**.001 (.18)**	**.008** (.09)	**.005** (.09)	**.009 (.08)**	**.027 (.06)**	.621 (.01)
Animal naming	40.15 (10.51)	42.79 (9.38)	39.04 (9.69)	45.29 (10.10)	39.81 (10.94)	44.38 (10.13)	43.57 (8.27)	42.38 (11.48)	**.038 (.10)**	**.011** (.08)	.953 (.01)	.477 (.01)	.531 (.01)	.189 (.02)
Excluded letter	24.79 (8.08)	31.89 (8.06)	23.14 (7.18)	30.81 (9.58)	27.14 (8.79)	31.90 (10.33)	24.76 (7.36)	26.81 (6.65)	**.140 (.07)**					
Phonemic switching	26.95 (7.47)	32.37 (8.85)	26.43 (7.47)	38.05 (11.46)	26.19 (7.43)	30.42 (8.15)	25.14 (7.63)	26.81 (7.23)	**< .001 (.23)**	**.002** (.12)	**.018** (.07)	.571 (.01)	**< .001 (.14)**	**.004 (.10)**
Semantic switching	26.10 (4.81)	26.95 (4.95)	25.14 (5.27)	27.71 (5.66)	25.19 (5.33)	29.90 (6.34)	26.24 (4.06)	27.24 (5.60)	**.022 (.11)**	.103 (.03)	**.008** (.09)	**.004 (.10)**	.094 (.04)	.186 (.02)

Note. The p-values refer to the interaction (group x time), controlling for performance on the Digit Symbol Substitution Test. Planned comparisons for the significant interactions were as follows: Contrast 1) initial letter fluency training, phonemic switching fluency training, active control vs. no-contact control (A, B, D vs. E), Contrast 2) initial letter fluency training, phonemic switching fluency training vs. active control (A,B vs. D), Contrast 3a) initial letter fluency training vs. active control (A vs. D), Contrast 3b) phonemic switching fluency training vs. active control (B vs. D), Contrast 4) initial letter fluency training vs. phonemic switching fluency training (A vs. B).

Transfer to untrained tasks

To examine generalization of training gains to standardized neuropsychological measures of cognitive functions (see Table 7), we chose tests according to the core processes of each verbal fluency subtest intended to be targeted in the training (processing speed, shifting, and inhibition). Furthermore, memory measures (short-term memory, working memory, and long-term memory) were included as these have been found to be related to verbal fluency performance (Rosen & Engle, 1997; Ruff et al., 1997).

A 4 x 2 repeated-measures ANOVA with group as between-subjects factor and time (pretest, posttest) as within-subject factor was conducted to assess whether the four groups differed in these six tests. For the Trail Making Test, Go/No-Go, N-Back, and episodic free recall, no significant interaction effect emerged (all ps $> .05$). However, a significant interaction was found on the Digit Span task ($p < .05$). We specified three contrasts to compare the four groups. First, comparison of the three activity conditions (initial letter fluency training, phonemic switching training and control activity) versus the no-contact control condition (A, B, D vs. E) revealed no differences in performance on the Digit Span task. Second, comparison of the two verbal fluency training conditions versus the control activity (A, B vs. D) revealed a significant difference ($t = 2.74$, $p = .008$, $\eta^2 = .09$). Third, we compared each training group separately with the active control group (A vs. D; B vs. D). Comparing performance after receiving initial letter fluency training revealed a marginally significant finding ($t = 1.97$, $p = .052$, $\eta^2 = .05$), and comparing performance after receiving phonemic switching training revealed a significant finding ($t = 2.75$, $p = .007$, $\eta^2 = .09$). Fourth, comparing the two training groups, we did not find a significant difference in performance on the Digit Span task.

Table 7. Mean test scores on untrained transfer tasks

	Initial letter fluency training (A) M(SD)		Phonemic switching fluency training (B) M(SD)		Active control (D) M(SD)		No-contact control (E) M(SD)		p-value η^2
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	
Trail Making Test (B-A)	52.71 (22.78)	46.14 (18.94)	51.00 (18.53)	48.89 (30.36)	58.14 (23.68)	49.85 (26.67)	57.33 (32.03)	38.95 (14.83)	.256 (.05)
Go/No-Go	19.84 (.50)	19.89 (.31)	19.95 (.21)	19.71 (.90)	19.14 (3.07)	20.00 (0.00)	19.76 (0.62)	20.00 (0.00)	.084 (.08)
Digit Span	10.05 (1.54)	11.10 (2.13)	10.61 (1.77)	12.00 (2.46)	10.90 (2.07)	11.05 (2.08)	11.00 (1.52)	11.42 (1.61)	**.012** (.13)
N-Back	11.73 (2.58)	11.05 (3.88)	11.85 (2.80)	12.70 (2.27)	12.43 (2.29)	12.71 (2.15)	11.65 (3.15)	12.90 (2.00)	.220 (.06)
Free recall	10.47 (3.39)	12.10 (3.18)	10.45 (3.74)	12.00 (2.80)	10.80 (3.36)	12.60 (2.83)	9.00 (2.93)	10.61 (2.94)	.842 (.01)

Note. The p-values refer to the interaction (group x time), controlling for performance on the Digit Symbol Substitution Test.

5.2.4 Discussion

The aim of the present study was to develop an intervention to improve verbal fluency performance in old age. A further aim was to design a non-traditional intervention that is short, easy to integrate in every-day life, and not relying on computer-based software. Besides training gains, we investigated whether we find training related improvements in other verbal fluency tasks as well as in untrained tasks.

More specifically, we predicted finding training gains in all three training tasks, and that these training gains differ across the three training groups. We found improvement throughout training for both, initial letter fluency training and phonemic switching training, suggesting that verbal fluency is improvable in healthy old age even after only three-weeks of intervention with a total training time of 90-minutes. The training gains in both groups were more or less the same. However, we did not find any performance improvement after excluded letter fluency training. On this task, participants started at a relatively high level, compared to the amount of words produced by participants of the other two training groups. As there were no differences between groups at pretest, except on the Digit Symbol

Substitution Test, it seems most likely that the excluded letter fluency task we used was relatively easy for older adults.

We had predicted transfer to other verbal fluency tasks. Analyses with the groups receiving initial letter training or phonemic switching training revealed transfer to tasks that were similar to the trained tasks. Moreover, the two training tasks led to different results. Initial letter fluency training led to transfer to only initial letter fluency administered with another initial letter than in the training. In contrast, training gains after phonemic switching training were not tied to the specific items of the training task, as these participants additionally increased performance on initial letter fluency.

Finally, we predicted transfer to untrained tasks, some of which involved the same underlying processes as targeted in the training (processing speed, shifting and inhibition). Consistent with our previous findings regarding performance improvements on verbal fluency after phonemic switching training, we found transfer to the Digit Span task for this group. Interestingly, participants showed performance improvements that were greater compared to the other four groups. This was the only significant finding for transfer to untrained tasks and, although it is promising, a note of caution is required. Nevertheless, this finding is in line with previous studies that reported improvements in several cognitive functions following task-switching or dual-task training (e.g., Bherer et al., 2005; Karbach & Kray, 2009). Our results extend these findings by demonstrating that task-switching in the context of verbal fluency could reveal performance improvements. The larger transfer effects after phonemic switching fluency training compared to the initial letter fluency training might be explained by the fact that, in addition to shifting processes, this training also required processing speed abilities, for example when switching between letters as fast as possible.

Our study further revealed an unexpected finding: the active control group improved performance in semantic switching fluency. The task chosen, talking about a specific topic, may have led to an activation of semantic knowledge. This task was designed to be similar to the trained tasks in all aspects, but without focusing on a specific cognitive process. It might have been better to include a non-semantic task as control activity. However, the fact that the active control group also showed an improvement is in concordance with previous findings on cognitive engagement. In fact, Stine-Morrow, Parisi, Morrow, and Park (2008) found cognitive performance enhancement after an intervention on engaged lifestyles. In addition, our finding also fits the hypotheses of the “Synapse Program” proposed by Goh and Park (2009). In this intervention study, older adults were randomly assigned to different conditions of engagement, for example quilting or digital photography, with the idea of general cognitive activation. Furthermore, as could be seen from Table 6, it is also not a negative transfer, in the sense that the three training groups would not be able to improve performance because of the training task interfering with the transfer task. Instead, the active control group improved performance above and beyond the two training groups and the no-contact control group.

From the findings of this study several implications can be drawn. First, we have demonstrated performance improvements of older adults through a 90 minutes training intervention using different versions of verbal fluency. Second, this study shows that the gains from such a short-term intervention can, although in a limited way, transfer to other, non-trained tasks. Given that we observed improvements across session 1 to 11, increasing the number of training sessions might lead to more transfer effects. Regarding practical implications, from collected reports of participants we know that the participants enjoyed to participate and looked forward to their daily phone call. Further applications of this training could be possible, for example as an activity for patients with mild cognitive impairment. Because the tasks are easy to administer and do not require many resources, they could be applied by caregivers. Thus both, verbal fluency tasks as well as providing a specific topic to talk for several minutes could be integrated in everyday lifestyles. However, before such applications can be unreservedly recommended more research is needed that supports or even extends the efficacy of the training intervention.

A limitation of this study is that we did not evaluate if the training effects would be maintained several months following the intervention. Unfortunately, we did not collect any data that addresses this issue, as our aim was to show verbal fluency plasticity and transfer to cognitive abilities in the first place. A further limitation of this study is that the no-contact control group was not recruited together with the other intervention groups. However, baseline performance of the no-contact control group did not differ from the four activity groups, including the Digit Symbol Substitution Test. Ideally, performance of the no-contact control group would have been assessed in a wait condition, providing training after the posttest. Finally, some studies have also shown evidence for age-related stability in phonemic fluency performance (Tomer & Levin, 1993; Van der Elst, Van Boxtel, & Jolles, 2012). This has been attributed to the fact that verbal fluency is recognized as a crystallized ability, along with general knowledge and vocabulary, which are largely influenced by education and acculturation (Horn & Cattell, 1967). Therefore, crystallized skills may be important determinants of the magnitude and direction of age effects on verbal fluency performance, especially on phonemic fluency performance.

Based on our findings, future studies might want to investigate if an increase in the number of sessions has a positive effect on transfer to other cognitive abilities and if training gains persist in a follow-up study. In addition, neuroimaging data that assess changes in the neural correlates of the trained function could provide insights into the specificity of the training effects and their neural basis. Furthermore, one might wonder why we did not include semantic fluency, as this variant has been identified to be more age-sensitive. In the first part, we were targeting some of the underlying cognitive processes that could be more easily targeted with phonemic fluency training. Future studies, however, could investigate the effectiveness of semantic fluency training and whether participants improve performance to a similar degree.

In conclusion, of main interest in this study was whether verbal fluency performance could be improved through a simple short-term intervention. The largest training gains and the most improvements on transfer tasks were observed after phonemic switching training. Finally on a broader level, the demonstration that performance benefits could be achieved in a short-term telephone-based intervention has practical utility, given that word finding difficulties are frequently reported by healthy older adults (Wierenga et al., 2008) and an impairment in verbal fluency performance is also found in patients with early Alzheimer's disease (Galasko et al., 1990).

5.3 Study 3: The influence of phonemic switching fluency training on task-switching performance and its neural correlates in older adults

5.3.1 Introduction

Aging affects cognitive functions differently, which is reflected in the common finding that, for some cognitive functions, age-related deficits are more pronounced than for others (for an overview see Glisky, 2007). To illustrate, older adults have been consistently found to exhibit impaired performance on tasks that involve basic cognitive processes like processing speed (Salthouse, 1996). Also, on higher level executive functions, a decrease in performance has been identified; for example, on tasks that assess working memory or task-switching (Verhaeghen & Cerella, 2002). Consequently, it goes without saying that these cognitive deficits could have an impact on older adult everyday activities. However, there are also other cognitive functions which are less affected by the aging process such as vocabulary or knowledge (Park et al., 2002).

There is increasing interest in improving cognitive functions in old age by means of different training interventions (Martin et al., 2011). Successful training gains and transfer effects have been reported after interventions targeting some of the above-mentioned cognitive functions. Thus, promising results have been observed with interventions targeting processing speed (Ball et al., 2002), working memory (Buschkuehl et al., 2008; Dahlin, Nyberg, et al., 2008) and dual-task or task-switching (Bherer et al., 2005; Karbach & Kray, 2009), to name a few.

In most training studies on older adults, computer-based training has been chosen to augment cognitive performance. However, especially in old age, it also may be worthwhile to consider other approaches, as not all older adults are comfortable working with computers (Dyck & Al-Awar Smither, 1994). In addition, the inhibition threshold for older adults to participate in a training study might be lowered using a non-computer-based approach. Several other training studies have adopted a different approach; for example, improving cognitive functions by means of an arts intervention (Noice et al., 2004), or the engagement in activities such as quilting or digital photography (Goh & Park, 2009). In these multi-domain training interventions transfer to a broader set of tasks is usually found (Lustig et al., 2009). Furthermore, these training activities might more easy to integrate into everyday lifestyles.

Promising findings on training gains and transfer effects have also been reported after a telephone-based intervention for older adults involving verbal fluency as a training task (Sutter, Zöllig, & Martin, in press). Besides the age sensitivity of verbal fluency, the task is frequently used in cognitive aging research and has been identified as having high diagnostic utility (Fisk & Sharp, 2004; Kempler et al., 1998; Monsch et al., 1992). After three weeks of telephone-based verbal fluency training, Sutter et al. (in press) identified training gains, and transfer effects to other verbal fluency tasks, as well as to an untrained transfer task. Of the three different verbal fluency training groups that were investigated, participants trained in phonemic switching fluency benefited the most from training. Accordingly, in this study, we investigated whether phonemic switching fluency training leads to improved performance on a computerized task-switching paradigm. More precisely, the aim was to examine whether a broader training intervention, similar to multi-domain trainings, involving more than one specified cognitive process, would lead to benefits on processes of an established task-switching paradigm. As the phonemic switching group showed the most benefits from training and shifting has previously been associated with performance on this task (Cauthen, 1978), we analyzed which of the commonly assessed processes in a task-switching paradigm were affected. Thereby we were hoping to shed light on the benefits of the training and the underlying mechanisms.

We evaluated the cognitive performance of three groups of healthy older adults before and after either 90-minutes of telephone-based verbal fluency training (training group), a control activity (active control group), or no activity (wait-list control group). We used a cued task-switching paradigm adapted from Cepeda, Kramer, and Gonzalez de Sather (2001). In this paradigm, different digits (1, 3, 111, or 333) are presented on a computer screen. Before the digits are presented, either the instruction “What number?” or the instruction “How many?” appears. Participants should either respond to the identity of the digits (i.e., the numerical value) in one task or to the quantity of digits in the other task. Within this paradigm, it is possible to distinguish two blocks. In pure blocks, the same instruction is presented repeatedly in the entire block, which refers to pure trials. In mixed blocks, both instructions are presented randomly. Moreover, within mixed blocks, there are two different types of trial. In stay trials, the same instruction is presented as in the previous trial (e.g., the trial “What number?”, followed by the trial “What number?”); in switch trials, the instruction changes from the previously presented task (e.g., the trial “What number?”, followed by “How many?”), which requires switching from one task to the other (Manzi, Nessler, Czernochowski, & Friedman, 2011).

Also, from these trial types, different forms of behavioral costs in relation to reaction times or response accuracy can be computed (Czernochowski, 2011). Mixing costs are obtained by subtracting pure trials from stay trials, and switch costs are obtained by subtracting stay trials from switch trials. Furthermore, to both types of cost different cognitive processes have been attributed. Mixing costs are believed to involve the coordination of task-sets (Monsell, 2003), which also includes task-set updating and maintaining multiple task-sets in memory (Manzi et al., 2011; Mayr, 2001; Meiran, 2000). By contrast, switch costs are thought to be associated with task-set reconfiguration, which involves switching the attention to the new task and its rules, as well as inhibition of the previous task-set (Monsell, 2003). In the present study, we were interested in investigating whether there is evidence of a change in mixing costs or switch costs after training in phonemic switching fluency.

Manzi et al. (2011) investigated performance on the above-mentioned paradigm in children, adolescents, and young adults. They found age differences for mixing costs, with young adults demonstrating less reaction time mixing costs than children. Using the identical paradigm, Czernochowski (2011) examined performance among younger and older adults and found that, in terms of mixing costs older adults performed slightly slower than young adults. With respect to switch costs, both studies found no differences between the age groups, indicating that this type of cost might be age-invariant. Accordingly, after phonemic switching training, we expected a decrease in reaction time mixing costs in the task-switching paradigm and thus an adaption to the performance of younger adults. Based on previous findings, we anticipated finding no significant training-related changes in switch costs.

Besides behavioral data, we were further interested in the underlying mechanisms improving cognitive performance after receiving phonemic switching training. There is evidence from previous training studies that training-induced changes in the brain can be detected using electrophysiological measures. To illustrate, Zöllig et al. (2012) identified different patterns of event-related potentials (ERPs) comparing older adults receiving a familiarization intervention with the sequence of stimuli in a prospective memory paradigm with a control group. Similarly, Berry et al. (2010) evaluated participants' performance before and after training, assessing ERPs and identified alterations after training in early visual processing during stimulus encoding. Maclin et al. (2011) studied changes in attention allocation after video game practice and observed changes after training in both the P3 and delta EEG. Electroencephalography is the neuroimaging method of choice when investigating changes elicited in the range of milliseconds (Goffaux, Phillips, Sinai, & Pushkar, 2006) and, as these studies indicate, using this technique can provide further information on training-induced changes in the brain. Therefore, we were interested in investigating whether we would find any alterations in electrophysiological measures after verbal fluency training that capture the neural effects of verbal fluency as it changes with training. In this regard, Czernochowski (2011) additionally investigated how younger and older adults differ in their neural correlates of task-switching performance and reported smaller antero-frontal and parietal ERPs of mixing costs for older adults versus younger adults. Similarly, we explored whether we would find any changes in amplitudes in comparable ERP locations after training in phonemic switching fluency. More precisely, in a first step, we expected finding mixing and switch costs in all groups at baseline. In addition and similar to the predictions for the behavioral data, we expected finding a change in mixing costs from pretesting to posttesting session for the training group.

5.3.2 Methods

Participants

Participants were sixty-three older adults (M = 71.65; SD = 5.3; range = 64 - 88 years). They were randomly assigned to one of three groups: a phonemic switching training group, an active control group, or a wait-list control group. Participants were recruited via advertisements in a magazine. All participants were native German speakers, with normal or corrected-to-normal vision, no history of neurological or psychiatric disorders, and no use of medications known to affect the central nervous system. Written informed consent was obtained from all participants and their participation was remunerated with CHF 30 (approximately 33 USD). The study was approved by the institutional ethics committee. Three participants dropped out during data collection because of their inability to complete the training or due to incomplete responses during testing sessions. Thus, behavioral analyses are based on the data of 60 participants. Due to technical problems during EEG recordings or too many artifacts in EEG data sets, we had to further exclude data of 4 participants, resulting in a total of 56 participants for EEG analysis.

Demographic and neuropsychological data of the three groups are shown in Table 8. The short version of the Geriatric Depression Scale (Sheikh & Yesavage, 1986) was administered and all participants scored beneath the cut-off score of 6. Verbal knowledge was assessed using a multiple-choice vocabulary test (MWT-B; Lehrl, 1977) and short-term memory was assessed using the Digit Span Forward task, adapted from the Nuremberg Aging Inventory (NAI; Oswald & Fleischmann, 2006). Furthermore, we administered the Trail Making Test (Reitan, 1971). The time to complete part B minus the time to complete part A was used to assess shifting. On these measures, all participants had scores within or above the average range, and performance across the three groups did not differ in any of these measures during pretesting session.

Table 8. Mean subject characteristics

	Phonemic switching fluency training	Active control	Wait-list control	Overall	p-value
Age	72.0 (4.7)	71.1 (6.2)	71.1 (5.2)	71.4 (5.3)	.801
Years of education	9.8 (1.8)	9.6 (1.1)	10.5 (2.9)	10.0 (2.1)	.366
GDS score	.63 (.84)	1.17 (1.2)	.50 (1.0)	.74 (1.0)	.106
MWT-B	32.52 (1.8)	32.94 (1.7)	32.35 (2.09)	32.59 (1.85)	.623
Digit span forward	8.09 (1.9)	8.95 (1.4)	9.00 (1.6)	8.63 (1.7)	.151
Trail Making Test B minus A	58.74 (34.6)	56.06 (29.5)	48.86 (24.6)	54.69 (29.9)	.553

Note. Standard errors are in parentheses. The p-values refer to the comparison of all five groups. GDS = Geriatric Depression Scale.

Training

Training intervention and control activity were carried out via telephone and required 15 sessions. Participants in the phonemic switching training group were asked to alternate between two given initial letters (e.g., “H” and “T”). Switching between the two letters was emphasized in the instructions. The verbal fluency stimuli that were used have been described in detail elsewhere (Sutter et al., in press). Participants performed two tasks in each training session, which required six minutes each day. To assess performance throughout training, the same letters were repeated in the training session one, six, and eleven. In order to complete the three weeks and to maximize transfer effects, training sessions continued through session 15. Participants in the active control group were asked about their opinion, thoughts and experiences on a given topic (e.g., “movies” or “traveling”) for the same amount of time. Participants of the wait-list control group were invited to the pre- and posttesting sessions without further contact between the two sessions. Identical phonemic switching fluency training was provided to this group after the posttesting session.

Procedure of the pretesting and posttesting session

We invited participants to the laboratory for a pretesting session in which baseline performance on a battery of cognitive tests and on a task-switching paradigm were assessed.

After the intervention, a posttesting session was carried out, in which the tests from the pretesting session were applied again.

Effects on different verbal fluency tasks. To assess effects on other tasks, three subtests of a German word fluency test (Regensburg Word Fluency Test; Aschenbrenner et al., 2000) were used. Initial letter fluency was assessed by asking participants to produce as many words as possible beginning with the letter S. Phonemic switching fluency required that participants produce words that alternately started with G and R, which were not used in the training. Semantic switching fluency was assessed by asking participants to alternately produce words in the categories ‘sports’ and ‘fruits’. The outcome measure for all three verbal fluency tasks was the number of correct responses produced over three minutes. The numbers of repetitions and errors, such as proper nouns, words with the same stem, and words that would not appear in a German newspaper or book, were not included in the total verbal fluency score.

Effects on an established laboratory task-switching paradigm. The task used was based on the design introduced by Cepeda et al. (2001). One of four possible stimuli (1, 3, 111, 333) was presented on a computer screen and participants were asked to respond to the instruction “What number?” in one task, and to the instruction “How many?” in the other task. Answers were given using the ‘1’ and ‘3’ key on the keypad in front of them.

Each trial started with a cue indicating the task to be performed for 300 ms and consisted of one of the two questions presented in an oval shape. To make cue detection easier, each question was consistently presented in either yellow or blue, which persisted throughout the entire experiment. After the cue, a fixation cross was presented for 300 ms. Thus the resulting cue-target interval lasted 600 ms. The target stimulus was presented for a maximum of 4000 ms and the following trial started after presentation of a fixation cross for 1000 ms.

The experiment consisted of pure and mixed blocks (see Figure 6). In pure blocks, the cues (“What number?” and “How many?”) before the stimuli remained the same. In mixed blocks, both cues were presented and participants had to switch between the two tasks. Stay and switch trials were presented with the same frequency. Two pure blocks were presented one after the other (one question each, consisting of 36 trials); thereafter three mixed blocks (each consisting of 96 trials), and finally two pure blocks again. In accordance with the study by Manzi et al. (2011), we counterbalanced response–hand mappings as well as the color and order in which the questions were presented across participants. In addition, to familiarize participants with the task, trials were preceded by 10 practice trials of each pure block and 20 trials of one mixed block.

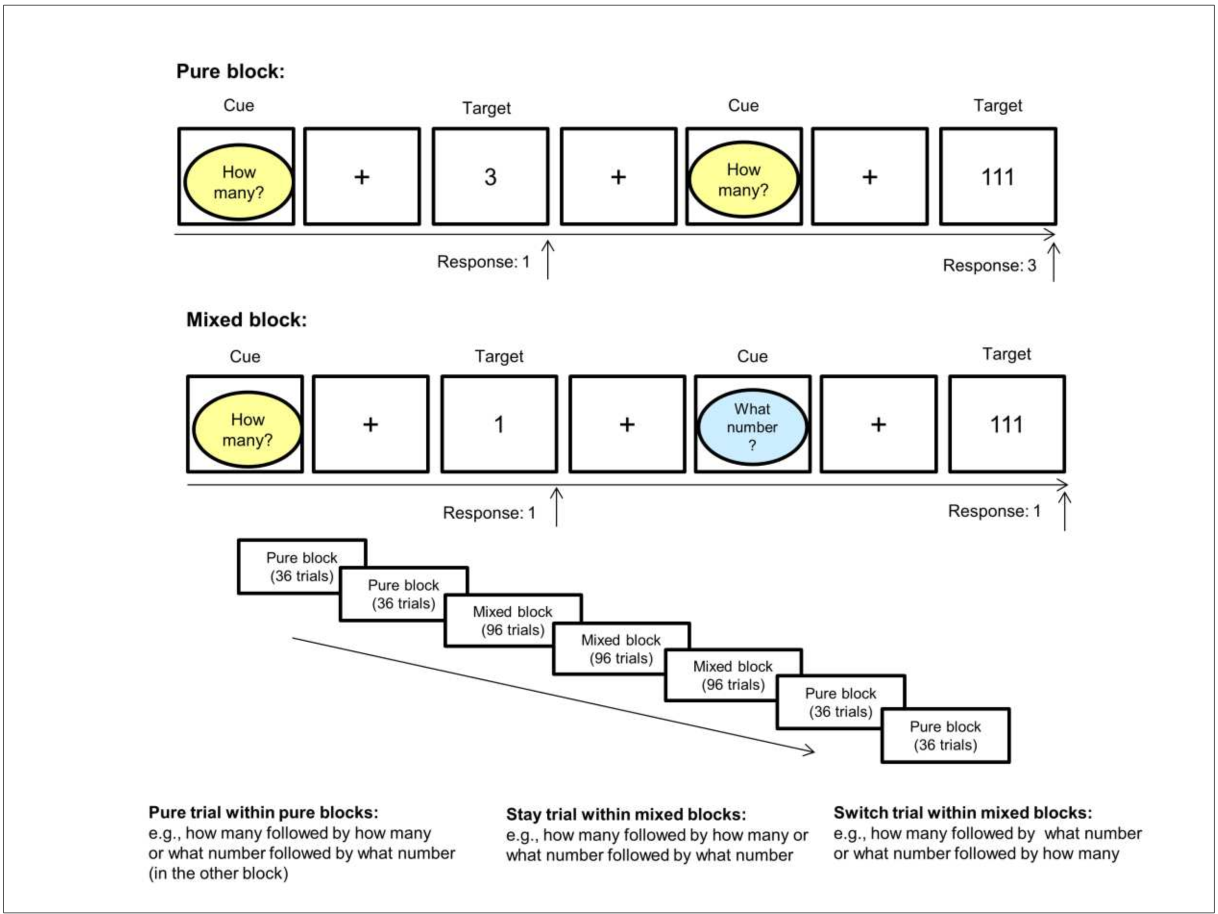

Figure 6. Experimental paradigm (adapted from Cepeda et al., 2001).

Participants were seated comfortably in a sound-attenuated and electrically shielded room. Data were recorded throughout the seven blocks, each lasting approximately four minutes, with a total of 144 per trial type condition (pure, stay, switch). Stimuli were presented centrally on the monitor within a colored box (each of the two questions in either yellow or blue) on a gray background.

Data acquisition and EEG recording

EEG activity was collected using a 64-channel actiCAP™ active electrode system (Brain Products, Munich, Germany). Electrodes were placed according to the extended 10-20 system using a ground electrode on the central forehead. Inter-electrode impedance was kept below 10 kΩ. A common average reference was used during recording. Also, during recording, no filter was applied. In order to control eye-movement artifacts horizontal and vertical electro-oculograms (EOG) were recorded bipolarly.

Data analysis

Behavioral data analysis of the task-switching paradigm. Data analysis was performed according to the criteria described by Manzi et al. (2011). Only correct trials with reaction times between 200 and 2800 ms were included. In addition, mean reaction times and standard deviations were computed for each participant and each of the three trial type conditions. All trials exceeding 2.5 standard deviations from the individual mean were excluded from further analysis. During the pretesting session, the mean trial numbers for each group (training vs. active control vs. wait-list control) in the three conditions were as follows: Pure (135 vs. 135 vs. 133), stay (131 vs. 132 vs. 131), and switch (131 vs. 130 vs. 130). At the posttesting session, the mean trial numbers were the following: Pure (136 vs. 138 vs. 137), stay (136 vs. 137 vs. 136), and switch (136 vs. 135 vs. 136). Furthermore, mean reaction times and the correct response rates for pure, stay, and switch trials were computed. Mixing costs were obtained by subtracting pure trials from stay trials, and switch costs were obtained by subtracting stay trials from switch trials.

ERP data analysis. For the ERP analyses, we only used trials that met the criteria for behavioral analyses. EEG data were corrected off-line for both vertical and horizontal eye-movement artifacts. The remaining artifacts (e.g., muscle activity) were manually rejected. EEG epochs extended from 100 ms prior to the cue until 600 ms following target presentation, using the pre-cue interval as baseline. For each group separate grand averages were obtained for each of the three trial type conditions (pure, stay, switch). For electrophysiological data analysis, mixing costs were examined by comparing the differences between pure and stay trials, and switch costs by comparing the differences between stay and switch trials. Before statistical analysis, a 0.5-Hz high-pass filter, a 30-Hz low-pass filter, and a 50-Hz notch filter were applied. ERP analyses were conducted at three regions of interest (ROIs). The first ROI included three central electrodes (Fz, FCz, Cz), based on electrodes chosen in previous studies using the identical task-switching paradigm (Czernochowski, 2011; Manzi et al., 2011) and similar topographic distributions of the mixing and switch costs. Due to previous findings of a component elicited in task-switch paradigms located in the posterior sites (Lavric, Mizon, & Monsell, 2008; Sohn, Ursu, Anderson, Stenger, & Carter, 2000), we specified two parietal ROIs, each including six electrodes (CP3, P3, CP5, P5, TP7, P7; respectively CP4, P4, CP6, P6, TP8, P8). Amplitude differences for all three ROIs were examined in the time window between 150 and 300 ms, based on time windows in which mixing and switch costs have previously been reported (Czernochowski, 2011).

Statistical analyses

To test for differences between the three groups in demographic characteristics as well as baseline cognitive performance, we applied one-way analyses of variances (ANOVAs). To evaluate the effects of training, we applied repeated-measures ANOVA including the training sessions one, six, and eleven. To measure effects on different verbal fluency tasks we applied repeated-measures ANOVA with the performance measures at pre- and posttesting session as dependent variables. The interaction terms (i.e., group x time) were chosen to interpret the training improvements between the different groups. To examine effects on an established task-switching paradigm we used Wilcoxon signed-rank test because the distributions of scores were non-normal. In a first step, we examined whether pure trials were significantly different from stay trials (i.e., to find mixing costs) and whether stay trials were significantly different from switch trials (i.e., to find switch costs). Second, we tested whether the three groups differed on these trial type conditions at baseline using Kruskal-Wallis test. To investigate whether these changed from pre- to posttesting session, we again performed Wilcoxon signed-rank tests for each group.

For the EEG data a 2 x 3 repeated-measures ANOVA was performed with trial type condition (pure, stay and switch) as within-subject factor and group as between-subject factor to analyze whether we find mixing costs and switch costs at baseline (main effect trial type) and whether the groups differed on these (trial type x group). To analyze whether we would find group differences on these mixing costs and switch costs from pre- to posttesting session, we performed a 2 x 2 x 3 repeated measures ANOVA with trial type (pure, stay) and time (pre, post) as within-subject factor and group as between-subject factor.

5.3.3 Results

Baseline data

At pretesting session, participants of the three groups did not differ in age, years of education and depression score. Furthermore, across all three groups no significant difference was observed in the cognitive measures (MWT-B, Digit Span forward, Trail Making Test B minus A; see Table 8).

Training gains

To investigate performance improvements across training, we applied repeated measures ANOVA including the training sessions one, six and eleven. Analyses revealed a significant main effect of time for the training group $F(2, 44) = 24.19$, $p < .001$, $\eta^2 = .52$, indicating that participants improved performance during training. Contrasts revealed that performance increased from session one to session six, $F(1, 22) = 29.19$, $p < .001$, $\eta^2 = .57$, however, there was no significant improvement from session six to session eleven, $p > .05$. In addition, training gains for the wait-list control group which received training after posttesting session, were also significant, $F(2, 36) = 21.90$, $p < .001$, $\eta^2 = .55$, with a significant increase in performance from session one to session six $F(1, 18) = 32.37$, $p < .001$, $\eta^2 = .64$, but again no significant increase from session six to session eleven $p > .05$. Comparison of training performance of the training group and the wait-list control group revealed a significant main effect of group, $F(1, 40) = 4.68$, $p < .05$, $\eta^2 = .10$. The two groups differed in performance gains from session one to session six, $F(1, 40) = 63.25$, $p < .05$, $\eta^2 = .60$, but not in performance gains from session six to session eleven, $p > .05$. As depicted in Figure 7, the wait-list control group showed a greater improvement during training than the shifting training group.

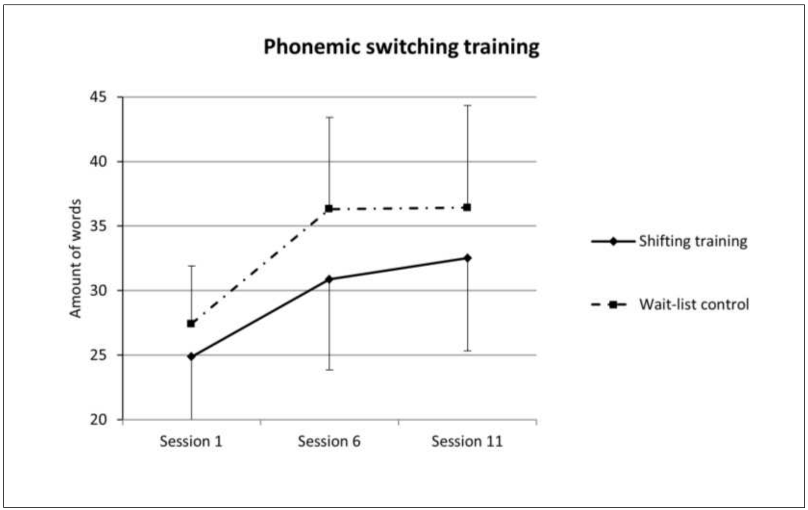

Figure 7. Training gains of the shifting training group and wait-list control group.

Effects on different verbal fluency tasks

A 3 x 2 repeated-measures ANOVA with group as between-subjects factor and time (pretest, posttest) as within-subject factor was conducted to assess whether the groups differed in the three verbal fluency tasks used. Consistent with findings from our previous study, besides a significant factor of time $F(1, 57) = 45.19$, $p < .001$, $\eta^2 = .37$, there was a significant group x time interaction on the phonemic switching fluency task, $F(2, 57) = 9.79$, $p < .001$, $\eta^2 = .16$, indicating that the change in performance from pretesting session to posttesting session was different in some groups than others. Contrasts revealed that the training group performed significantly better than the wait-list control group, $t = .4.09$, $p < .001$, $\eta^2 = .22$, as well as the active control group $t = .3.29$, $p < .01$, $\eta^2 = .15$. On the initial letter fluency task and the semantic switching fluency task, there was besides a significant factor of time, $F(1, 57) = 41.04$, $p < .001$, $\eta^2 = .40$; $F(1, 57) = 7.36$, $p < .01$, $\eta^2 = .11$, no significant group x time interaction or main effect of group (ps > .05), suggesting that the three groups did not differ on these tasks.

Effects on an established laboratory task-switching paradigm

All participants were tested on a task-switching paradigm at pre- and posttesting session. First, we investigated whether we find mixing costs as well as switch costs at pretesting session for the reaction times and correct response rates. Wilcoxon signed-rank test were used. Overall, pure trials were significantly different from stay trials for reaction times and the correct response rates, $z = -.654$, $p < .001$, $r = -.06$, $z = -3.20$, $p = .001$, $r = -.03$, indicating that responses on stay trials were slower and more errors occurred than on pure trials – in other words, there were mixing costs. However, stay trials were not significantly different from switch trials in neither the reaction times nor the correct response rates (ps > .05), which indicates that there were no switch costs. Due to this finding, for the following analyses, we focused on mixing costs. Using Kruskal-Wallis test, the three groups did not differ on pure and stay trials for reaction times and correct response rates at pretesting session (ps > .05). Furthermore, we investigated whether performance changed from pre- to posttesting session (see Table 9). Findings revealed that participants of the training group showed a significant decrease in reaction times from pre- to posttesting session.

Table 9. Correct response rate and mean reaction times obtained from mixing costs for the three groups

	Correct rate stay-pure difference					Reaction time stay-pure difference				
	pre M (SD)	post M (SD)				pre M (SD)	post M (SD)	z	p	r
Training group (N=23)	-1.48 (4.25)	-.823 (2.46)	.730	465	.11	213.20 (171.144)	149.62 (105.12)	-2.01	**.045**	-.30
Active control (N=19)	-.603 (3.27)	-.713 (2.16)	.155	877	.03	166.86 (181.78)	134.45 (144.93)	-1.59	.113	-.27
Wait-list control (N=21)	-1.50 (2.73)	-.489 (1.76)	1.16	247	.02	238.08 (265.64)	169.49 (169.81)	-1.64	.100	-.26

Electroencephalography

To investigate the underlying neural mechanisms involved in phonemic switching training, we recorded event-related potentials (ERP) during the task-switching paradigm at pre- and posttesting session and examined the frontal central ROI, as well as the left- and right posterior ROIs. As we did not find switch costs, we focused on mixing costs for the following EEG analyses. Scalp topographies and grand averages of the electrode FCz and P4 of pure and stay trials are depicted in Figure 8 and Figure 9. For all ROIs, we found at pretesting session a significant main effect of trial type across all groups, indicating that pure trials were significantly different from stay trials, (central: $F(1, 55) = 50.64$, $p < .001$, $\eta^2 = .47$; left: $F(1, 55) = 27.40$, $p < .001$, $\eta^2 = .33$; right: $F(1, 55) = 24.99$, $p < .001$, $\eta^2 = .31$). Furthermore, the groups did not differ on the mixing costs at pretesting session (ps. > .05). We analyzed whether we would find group differences on these mixing costs from pre- to posttesting session and performed a 2 x 2 x 3 repeated measures ANOVA with trial type (pure, stay) and time (pre, post) as within-subject factor and group as between-subject factor. For the central ROI, we found a significant main effect of trial type $F(1, 53) = 61.29$, $p < .001$, $\eta^2 = .54$, indicating that we did find mixing costs for all trials types. However there was no significant interaction with group ($p < . 05$). For the left-posterior ROI, we found besides a significant main effect of trial type $F(1, 53) = 40.50$, $p < .001$, $\eta^2 = .43$, a significant interaction of trial type x time x group, $F(2, 53) = 3.33$, $p < .05$, $\eta^2 = .11$. At the level of each group, we found for all groups a significant main effect of trial type (ps < .01), indicating that there were mixing costs in all three groups. Moreover, analyses revealed a marginally significant interaction (trial type x time) for the phonemic switching fluency group, $F(1, 21) = 4.02$, $p = .058$, $\eta^2 = .16$, and the active control group, $F(1, 16) = 3.28$, $p = .089$, $\eta^2 = .17$, and no significant interaction for the wait-list control group. For the right-posterior ROI across all three groups, we also found a significant main effect of trial type $F(1, 53) = 42.27$, $p < .001$, $\eta^2 = 45$, as well as a significant interaction of trial type x time x group, $F(2, 53) = 3.45$, $p < .05$, $\eta^2 = .11$. Further analyses on the group level revealed a significant interaction of trial type x time for the phonemic switching group $F(1, 21) = 5.46$, $p < .05$, $\eta^2 = .21$, and a marginally significant finding for the active control group $F(1, 16) = 4.33$, $p = .054$, $\eta^2 = .21$. Again, no significant interaction emerged for the wait-list control group.

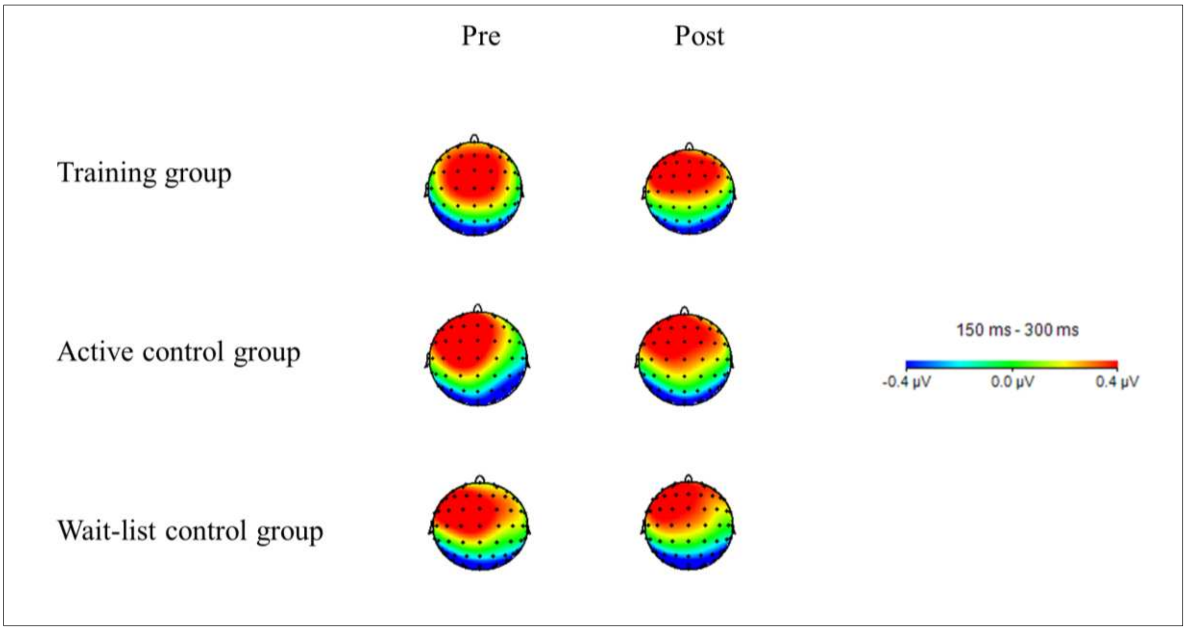

Figure 8. Scalp topographies of pure and stay trials for the time window 150 to 300 ms.

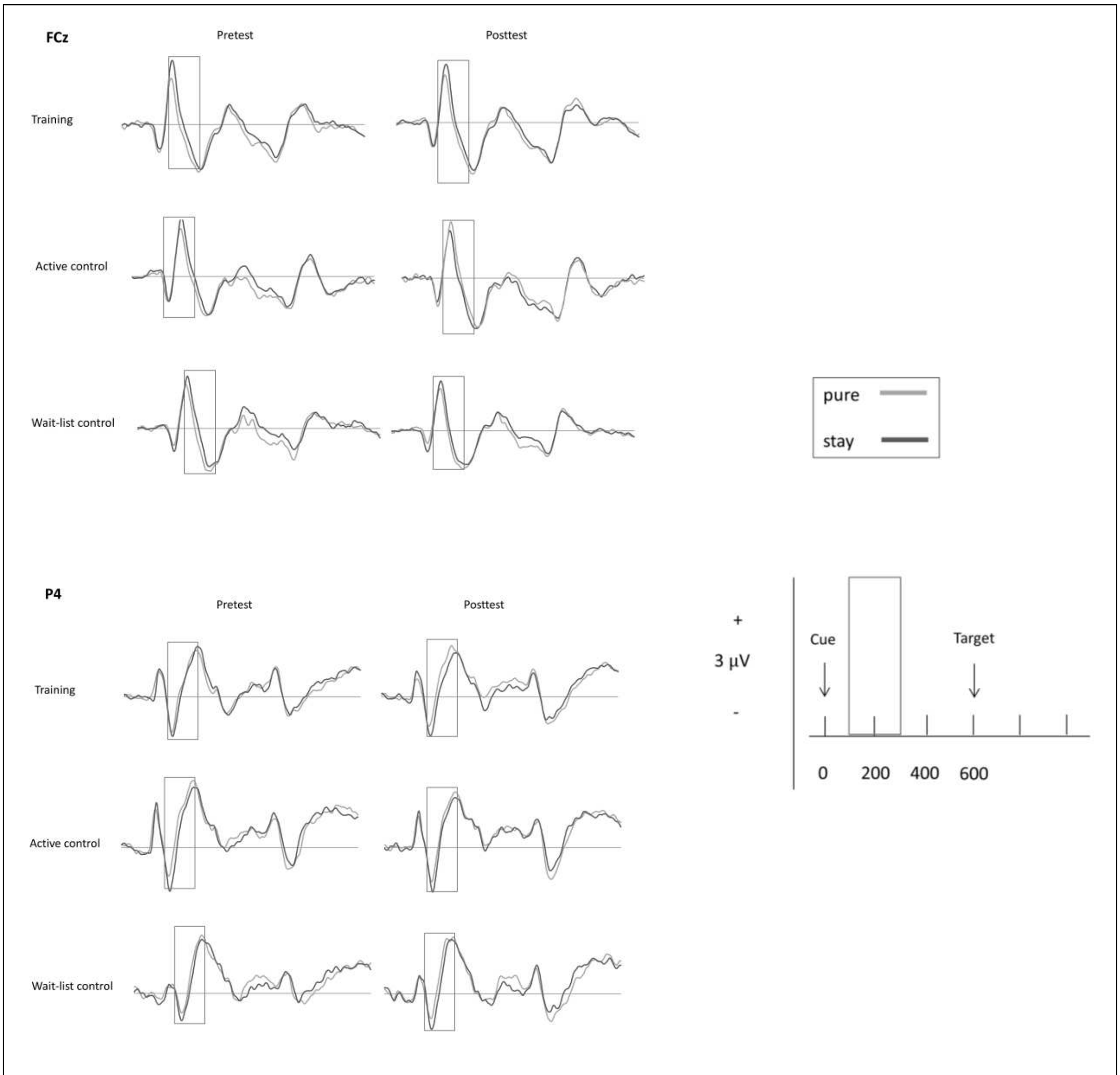

Figure 9. Grand averages for pure and stay trials.

Note. Vertical rectangles indicate the time window used for analysis.

5.3.4 Discussion

The aim of the present study was to evaluate performance on a task-switching paradigm after phonemic switching training, compared to performance after control activity or no activity. Besides behavioral data, ERP correlates were recorded in all three groups. To summarize the results, the training group showed improvements during training and reduced reaction time mixing costs on a cued task-switching paradigm. Consistent with these behavioral finings, ERP analyses suggest group differences in posterior ERP correlates, with a change in mixing costs from pre- to posttesting session for the phonemic switching group. These findings indicate that a broad training intervention, in which shifting - among other processes - has previously been associated (Cauthen, 1978), has a positive effect on processes assessed in a task-switching paradigm (i.e., mixing costs). From a theoretical perspective, this approach helps shedding light on the processes involved in training.

The results of the training gains replicate and extend previous findings (Sutter et al., in press). Regarding training, performance of the phonemic switching fluency training group significantly improved across session one to session six. However, training gains were less pronounced compared to the previous verbal fluency training study, where an additional improvement was found from session six to session eleven. Both training groups started at the same level; that is, between 25 and 30 words in three minutes. In session six and session eleven, however, the training group in the present study exhibited less increase in performance compared to the training group in the previous study (i.e., circa 33 versus 40 words). The reason for this difference is unclear, as the identical training protocol was used.

Interestingly, participants of the wait-list control group, which received the same training after posttesting session, exhibited more training gains than the actual training group. This finding is in line with other previous research reporting more pronounced effects for the wait-control conditions when using the same training as the actual training group (e.g., after cognitive-behavioral group training in the treatment of tinnitus; Kroner-Herwig et al., 1995). This pattern of results could be explained by the fact that participants' knowledge of a delayed beginning of the training might increase their motivation until it finally starts. It is also important to note, that in our study, the training group and the wait-list control group did not differ on any cognitive or emotional measures at pretesting session, which could have explained these different training outcomes. Future studies might extend the investigation of the wait-list control condition and might also establish what other factors, such as motivation or personality, could explain this observation.

Regarding findings on the task-switching paradigm, several interesting results were identified. First, we found mixing costs in reaction times and correct response rates; however, we were unable to find switch costs in either of the two measures. That is, when the same trial was repeated, participant's performance was better on pure trials in pure blocks than on stay trials in mixed blocks. Within mixed blocks, however, there was no difference between trials which required switching and trials on which the task was repeated. Mixing costs have been associated with the selection and maintenance of a task-set as well as the active coordination of two or more task-sets (Manzi et al., 2011; Mayr, 2001). As we were only able to detect mixing costs, it seems more likely that it was central to know for participants whether the same task would be repeated throughout the block or whether it was likely that the task could be replaced by the other task. The mind-set to know what block is currently performed would then be more important than to actually switch between two tasks. This relates to the finding that older adults have been found to rely to a greater extent on set-updating processes compared to young adults (Mayr, 2001).

Second, we identified a significant improvement for the phonemic switching training group in reaction time mixing costs from pre- to posttesting session. This pattern of results suggests that the training might have affected cognitive processes associated with mixing costs. For example, reaction time mixing costs might have been improved through the active maintenance of the relevant task-set in memory. In addition, it could be that participants experienced a higher memory load during training than during task-switching performance. More precisely, the training task, unlike the task-switching task, required knowing what words had been mentioned previously. Kramer et al. (1999) found that after a task-switching training, older adults improved performance to the level of younger adults when memory load was low. However, an increased memory load on the laboratory task revealed no benefit from training. On this basis, it is more likely, that in the present study a higher memory load during training might have facilitated task-switching performance in the laboratory task. Yet, we did not find a change in mixing costs consisting of the correct response rate which might be due to ceiling effects; participant’s correct response rate during pretesting session was 96 % in pure trials and 95 % in stay trials. This is consistent with findings reported by Czernochowski (2011), where older adults committed fewer errors than younger adults (1.67 % versus 3.55 %) and more errors occurred on stay trials compared to pure trials. In the present study, however, during posttesting session the correct response rate was 99 % in pure trials and 98 % in stay trials. This indicates that towards the top, no further improvement was possible, which could be considered as a limitation in our study. Future investigations could therefore involve studying the effects on a different task-switching paradigm that allows improvements in response accuracy.

Third, regarding electrophysiological data, we did find mixing costs in all three ROIs using the identical cue-target interval (600 ms) and a similar time window as reported in the study by Czernochowski (2011). We further did find group differences in the interaction trial type x time in left and right posterior electrode locations. More precisely, changes in mixing costs from pre- to posttesting session were found for the training group and at a trend level for the active control group. In recent research, it has been suggested that the posterior parietal activity in task-switching paradigms might reflect the anticipation and selection of task-relevant aspects of the cue (Goffaux, Phillips, Sinai, & Pushkar, 2008; Rushworth, Passingham, & Nobre, 2002). Although it is difficult to generalize ERPs to specific aspects of cognition (Maclin et al., 2011), in our study differences found across the two testing session could be related to performance improvements in training. That is, in the training task, anticipation of the next task-set and selecting task-relevant aspects were also relevant. Furthermore, particularly the selection of task-relevant aspects might have been relevant in the control task performed by the active control group, as well, which could explain the change observed in the ROIs of this group, albeit found on a trend level.

To conclude, the present study pursued an ambitious objective in several ways. It investigated the effects on a computer-based task-switching task after a short-term non-traditional cognitive intervention with older adults. Besides the training group, the study comprised two control groups - an active control group and a wait-list control group. Furthermore, the longitudinal assessment combined behavioral and electrophysiological data. From this investigation, interesting and promising results were obtained. First, we found evidence for training gains after phonemic switching training in the training group. Most surprisingly, these training gains where even more pronounced in the wait-list control group. Second, the training group demonstrated behavioral performance improvements on a task-switching paradigm, in line with training-induced changes measured by ERP correlates, most notably in posterior electrode locations. Together with findings from previous studies, this suggests that the training might have elicited changes in the anticipation or selection of related aspects of the task-switching task. On this basis, the present study contributes to the understanding of performance changes in older adults and adds up to the investigation of changes in the brain and the mechanisms underlying these changes (Glisky, 2007).

6 General discussion

This chapter discusses the main findings of the presented studies and relates these findings to the aims formulated in the introduction. For each study implications and future studies will be discussed. The present work ends with an outlook and some conclusions that can be drawn from the findings of the three studies.

6.1 Summary and discussion of results

6.1.1 Relation between cognitive functions and five variations of verbal fluency measures

The overall goal of the present work was to design a short training intervention, which is easy to integrate into everyday lifestyle. As a means to investigate the benefits of such an intervention, verbal fluency was chosen as the training task. However, before a cognitive task can be applied to training, careful task analysis is required to learn which cognitive processes are involved in performance of the training task and to select the appropriate transfer tasks (Lustig et al., 2009). Therefore, the aim of the first study was to clarify the relation of different verbal fluency subtests with cognitive variables. In addition to the frequently used two verbal fluency subtests, initial letter fluency and animal naming (Tombaugh et al., 1999), we expanded the number of subtests by assessing phonemic switching fluency, semantic switching fluency, and excluded letter fluency. Moreover, we assessed several cognitive variables that previously had been assumed to be required for verbal fluency performance, such as processing speed, verbal knowledge, shifting, inhibition, episodic memory, and working memory. We controlled for the relation with other background variables such as age, gender, education or subclinical depression. Furthermore, the relations between the verbal fluency subtests and cognitive variables were also compared across two time conditions (i.e., the first minute versus the third minute of verbal fluency performance). A different pattern of related cognitive variables with each verbal fluency subtest was expected.

The findings supported the hypothesis and revealed that performance on each of the five verbal fluency subtests required a different pattern of cognitive variables. Regarding the two most commonly used subtests, performance on initial letter fluency correlated positively with processing speed, as the only significant outcome, in the first as well as the third minute of task performance. This finding seems consistent with previous studies (Salthouse et al., 2003).

In contrast, performance on animal naming correlated with verbal knowledge and episodic memory in the first minute while shifting and episodic memory correlated in the third minute. This indicates that these two subtests, which both are often used to assess executive functions (Phillips, 1999), are in fact associated with rather different cognitive processes. Furthermore, an interesting picture emerged for the remaining three more complex subtests. Similar to the initial letter fluency subtest, performance on phonemic switching fluency correlated positively with processing speed and additionally with episodic memory and shifting in both the first and the third minute of task performance. On the other hand, performance on semantic switching fluency was similar to phonemic switching fluency in the first minute involving processing speed and shifting; however, no significant correlation could be found in the third minute. In addition, the most complex pattern emerged for performance on excluded letter fluency. In the first minute, performance correlated with processing speed and in the third minute with episodic memory and inhibition.

Overall, the findings seem to indicate that the two most frequently used subtests do not involve the same processes. Furthermore, for two of the phonemic fluency measures, initial letter and phonemic switching fluency, the cognitive processes involved remained the same with prolonged task duration. Semantic switching as well as excluded letter fluency revealed a less clear picture, with a shift in or a lack of associated cognitive variables with prolonged task duration. Table 10 presents an overview of some of the cognitive processes associated with verbal fluency performance.

Table 10. Pattern of cognitive processes and other variables associated with verbal fluency performance

	Processing speed	Shifting	Inhibition	Working memory	Verbal knowledge	Episodic memory	Other*
Initial letter fluency	+++	+	-	-	-	-	Age, education
Animal naming fluency	+	++	-	-	++	+++	Age, semantic network
Excluded letter fluency	++	+	++	+	-	++	Age
Phonemic switching fluency	+++	+++	+	-	+	+++	Education
Semantic switching fluency	++	++	-	-	-	-	Age, subclinical depression, semantic network

Note. *Other = other factors that could be associated with task performance

By focusing on phonemic fluency subtests, the findings indicate that even the three subtests differ with respect to the cognitive processes involved. To illustrate, for each phonemic verbal fluency subtest, a specific cognitive process could be singled out, although not exclusively correlated, to characterize the corresponding subtest. Processing speed appeared to account for initial letter fluency performance, shifting for phonemic switching fluency performance, and inhibition for excluded letter fluency performance.

By combining the neuropsychological and the cognitive perspective, we identified a different pattern of associated cognitive variables. Neuropsychologists are interested in localizing cognitive functions in the brain, in addition to concluding on the specific impairments in different cognitive domains caused by brain damage. Therefore, the findings of tests of executive functions are based mainly on the data collected from frontal lobe patients (Luszcz, 2011), which also applies for verbal fluency (Perret, 1974). As hypothesized and depicted in Figure 2, the different verbal fluency subtests revealed to have different relations with selected cognitive variables. If different processes are involved, different brain areas might be active when performing each subtest. Therefore, verbal fluency from a neuropsychological point of view seems to be an atypical measure of executive functions. Other measures commonly used to assess executive functions, such as the Tower of London and the Wisconsin Card Sorting Test (Salthouse et al., 2003), consist only of one test (and not different subtests), and therefore involve more clearly defined cognitive processes. Thus, adding the cognitive perspective has brought benefit from a neuropsychological point of view. In addition, from the cognitive perspective, which focuses on the underlying cognitive processes (Luszcz, 2011), verbal fluency subtests could be compared to the Verbal Learning and Memory Test (VLMT; Helmstaedter et al., 2001). The VLMT also comprises different subtests, all of which are used to assess different memory processes (e.g., learning, free-recall, and recognition).

Summary

In summary, examining the pattern of relations with other cognitive variables is a useful way to investigate what is assessed by the cognitive measure. In this study, this was applied to various verbal fluency subtests. Different combinations of associated cognitive variables were observed for each subtest. More precisely, we found a different pattern of associated cognitive variables within the three phonemic fluency subtests. This demonstrates that verbal fluency is not a uniform measure and caution should be applied when using these subtests. After investigating the cognitive processes underlying verbal fluency performance, we are now in the position to design a training intervention with verbal fluency as training task and to select corresponding transfer tasks.

Implications

As an implication, the different relations among all verbal fluency subtests and related variables suggest that the five subtests should be regarded as separate tests. By applying verbal fluency in clinical or experimental settings, investigators usually state to assess executive functions (Phillips, 1999). However, our findings indicate that the subtests vary in the cognitive processes involved. Accordingly, it should always be specified with which subtest and with which time criterion verbal fluency was assessed. Additionally, several subtests could be used within a setting, depending on the cognitive process under the investigation.

It would also be possible to combine the cognitive perspective with a more personality-based or emotion-based perspective. That is, research on emotion and personality works with multi-dimensional constructs requiring valid measures (Edelstein & Segal, 2011). To illustrate, anxiety could be measured physiologically (e.g., by physiological recordings), cognitively (e.g., with self-reports) or behaviorally (e.g., with direct observation). In general, none of these methods is more appropriate than the other; rather, a multi-method approach has been recommended (Edelstein & Segal, 2011). From the literature it is also known that anxiety impairs efficiency on cognitive performance (Eysenck, Derakshan, Santos, & Calvo, 2007). In addition, several cognitive functions might be associated differently according to the levels of anxiety (e.g., executive functions versus processing speed). However, this might also depend on the method, with which anxiety is assessed. By combining the multi-dimensional approach used in emotion and personality research with the cognitive perspective, future studies could investigate the relation between the outcomes of each of the three assessment methods of anxiety and different cognitive functions.

Future research

Future studies should investigate aspects of verbal fluency and cognitive processes. Particularly more research is needed on semantic switching fluency. As described above, especially within the third minute of task duration, it is not clear what other variables are associated with performance on this subtest. A glance at the literature reveals a lack of research regarding semantic switching fluency. For example, it could be possible that performance on this task depends to a greater extent on the connectivity and the density of the semantic network. The findings should be replicated and extended by including categories different from fruits and sports, for example, articles of clothing and flowers (see Regensburg Word Fluency Test; Aschenbrenner et al., 2000). This would provide more information whether our finding is specific to the two categories used. Furthermore, it could be examined whether the same amount of words would be produced when the identical categories are provided separately.

In addition, future studies could investigate developmental aspects. For example, how the pattern of cognitive variables associated with each verbal fluency subtest would differ across the lifespan. Children, for example, might have a less dense semantic network than adults. This and other investigations on performance differences across the lifespan might reveal more insights into semantic switching fluency.

Future studies could also utilize our findings when designing training interventions. Multi-domain training interventions use mainly training activities for which the underlying processes are not known. However, as can be seen from our findings, even small changes in instructions can lead to the association of different patterns of cognitive processes. Therefore, greater efforts should be made in future multi-domain training studies to identify the underlying processes before applying a training task.

6.1.2 Training effects using three variations of verbal fluency targeting processing speed, shifting, and inhibition

Evidence from previous studies suggests two promising training approaches, process-based interventions and multi-domain interventions (Noack et al., 2009). Although both approaches revealed promising findings, each approach has some disadvantages. To illustrate, in process-based training interventions rather monotonous tasks are used (Boot & Blakely, 2011), which are difficult to integrate in everyday activities. On the other hand, in multi-domain training interventions mechanisms behind the training improvements are not ultimately clear, which complicates selecting appropriate transfer tasks (Lustig et al., 2009). Therefore, the second aim of the present work was to evaluate a training intervention that utilizes the advantages of both approaches by using verbal fluency as a training task. This task is in the current setting easy to integrate into everyday life, short and diverse. Furthermore, due to study 1 underlying processes have been identified. The findings of the first study indicated that a different pattern of cognitive variables (the most prominent: processing speed, shifting, and inhibition) was required on the three phonemic fluency subtests, initial letter fluency, phonemic switching and excluded letter fluency. In study 2, we investigated plasticity in performance on each of the three subtests as well as transfer to tasks involving the same underlying processes as the training tasks. Participants were assigned to one of three training groups (initial letter, phonemic switching, or excluded letter) or one of two control groups (active control or no-contact control). A computer-based training approach was avoided, as verbal fluency lends itself well to be trained over telephone. The findings revealed training gains for initial letter fluency training and phonemic switching, but not for excluded letter fluency. Moreover, after initial letter fluency training and phonemic switching training, transfer to other verbal fluency tasks was found. In addition, phonemic switching training led to improvement in an untrained memory task.

Thus, there seems to be evidence for cognitive performance improvement through verbal fluency training, specifically in processes that have been found associated with verbal fluency performance. It was especially apparent for phonemic switching fluency, which revealed the most training gains in addition to transfer effects. In study 1, we found that phonemic switching fluency consistently involved the same process as initial letter fluency (i.e., processing speed) in addition to episodic memory and shifting throughout the two time conditions.

In addition, the second study revealed another interesting result. That is, not only two training groups exhibited transfer to other verbal fluency tasks, but also the active control group revealed an improvement in semantic switching fluency. As explained earlier in study 1, the underlying processes of performance on this task are unknown. It is possible that with our training activity (i.e., talking about a given topic for six minutes), the semantic network might have been activated. Moreover, during the six minutes, the topic usually was considered from different angles, which might have also involved shifting processes. A further explanation could involve the fact that someone listened to the participants with interest and appreciation, which could have led to an improvement in self-confidence. Further empirical testing is needed to find out the reasons for an enhancement in this group. It is not clear whether this group would have exhibited an increase in performance if a different control activity would have been chosen, in spite of the fact that the control activity was chosen carefully with the intention not to target a specific underlying cognitive function.

Summary

To sum up, the findings seem to demonstrate that a telephone-based cognitive intervention of 90 minutes significantly improved cognitive performance in healthy older adults beyond the improvements in the active control group. The findings provide the basis for cognitive interventions that could easily be integrated into everyday lifestyles and are still targeting specific cognitive functions.

Implications

In the second study, we found performance improvements after a short-term training intervention of only three weeks. That is, no complex and long training intervention was used. The greatest improvements were found in phonemic switching fluency involving several processes with stability in these across different time conditions. This is consistent with the finding that process-based training interventions reveal little transfer, as usually only one process is targeted and in broader multi-domain trainings the underlying processes are usually unknown. In other words, future interventions might reveal promising results when using tasks involving several processes with little change during task execution. Furthermore, evidence shows that the choice of the control activity influences the findings, since performance of the actual training group is compared to the control group.

Future research

The current findings could generate further studies. It is still unclear why the participants trained in excluded letter fluency did not reveal any improvement. A study could be conducted to find out whether this is caused by the higher performance of this group during session one, compared to the other two groups. Moreover, for the phonemic switching training group, one could argue, that this training should target shifting. Therefore, it would be worthwhile to investigate transfer to a broader battery of tasks involving shifting. In addition, it would be an obvious step to look for evidence from neuroscientific research to support current training-induced changes.

Also, further applications of this training could be conceivable, for example, by adapting the training to another group of participants. Semantic fluency subtests as a training task could also be examine more extensively (e.g., animal naming training intervention for healthy old adults), as some studies found an even greater age-related decline in semantic subtests (e.g., Tombaugh et al., 1999). Moreover, the benefits of semantic fluency training in patients with mild cognitive impairment or Alzheimer’s disease could be investigated. An early stage of Alzheimer’s disease is characterized by commonly subtle problems with naming and verbal fluency, which deteriorate to language problems in the middle phase of disease (Chan, Butters, Salmon, & McGuire, 1993).

Furthermore, the ultimate goal of training interventions is to improve transfer to everyday activities and future studies should investigate this aim more extensively. One way to assess transfer to everyday activities is by self-reported measures (Lustig et al., 2009). However, they capture only the subjective side of improvements in everyday activities. In addition, few standardized measures are available. These have often been designed for the use in clinical settings, with the assumption that they do not adequately assess performance in healthy old adults (Lustig et al., 2009). One of the few studies that investigated transfer to aspects of functional activities was the study of Ball et al. (2002). To illustrate, the authors examined everyday problem solving through the correct identification of information on medication labels and everyday speed by assessing the time needed to find groceries among several items on a shelf. Regarding the second study of the present work, new task designs would be needed to assess performance on everyday tasks requiring speed, shifting, inhibition, or communication skills. What remains is the use of neurophysiological measures, which offer a good alternative to investigate the performance on laboratory tasks as well as benefits of training (Maclin et al., 2011).

6.1.3 Phonemic switching fluency training targeting shifting reveals effects on specific processes assessed in a task-switching paradigm with evidence from event-related potentials

Verbal fluency training is considered as a broader training intervention than traditional process-based training interventions, as it involves more than one specified cognitive process. After providing evidence for cognitive changes after verbal fluency training, this study investigated the effects of such training on specific processes assessed with an established task-switching paradigm. As suggested by Lustig et al. (2009), research on the neural basis of cognitive training and transfer effects could clarify the underlying mechanisms of intervention effects. Therefore, behavioral data was combined with the application of EEG. Training gains, effects on other verbal fluency tasks, and effects on a computerized task-switching paradigm were assessed in a phonemic switching training group, an active control group and a wait-list control group. Training and control activity was provided five times a week over three weeks.

An advantage of study 3 is the use of a task-switching paradigm, which lends itself to detailed analysis of the processes involved. Two processes are commonly distinguished in task-switching paradigms. Mixing costs refer to an increase in reaction time and error rate in mixed blocks that include both tasks, contrary to pure blocks that include one task. Switch costs are associated with switching between the different tasks (Manzi et al., 2011).

Regarding task-switching performance, increased mixing costs have repeatedly been found among older adults compared to young adults (Kray, 2006).

Behavioral analysis of the third study of the present work revealed besides training gains a significant decrease in reaction time mixing costs after phonemic switching training. Regarding the electrophysiological outcomes, significant group differences in ERP correlates of mixing costs were observed from pretest to posttest in posterior electrode locations. Functionally, the change in activation in mixing costs of the training group might be associated with the coordination of task-sets, which also includes task-set updating and maintaining multiple task-sets in memory (Monsell, 2003). Recent research, has suggested that the posterior parietal activity in task-switching paradigms might reflect the anticipation and selection of task-relevant aspects of the cue (Goffaux et al., 2008; Rushworth et al., 2002).

These findings seem to suggest that the training group might have benefitted from phonemic switching training, as the findings from ERP analyses supported the change in performance in the task-switching paradigm. Furthermore, no significant decrease in reaction time or error rates of mixing costs was found in both control groups. Moreover, both behavioral and electrophysiological findings seem to fit together, despite the fact that different outcomes were examined in behavioral and ERP analyses. While behavioral data involved reaction time and correct response rate, ERP data involved mean amplitudes for correct responses in a selected time window (between 150 and 300 ms) and selected regions of interest of central and parietal electrodes for a clearly defined timeframe, the cue-target interval. That is, ERP analyses for this task-switching paradigm provided a greater choice of outcome variables.

In addition to the combination of behavioral and neurophysiological measures, a wait-list control condition was included, in which participants received training after the posttest. Surprisingly, they exhibited larger improvements across the training sessions compared to participants in the actual phonemic switching fluency training group. However, the question remains what effects may have been triggered by the waiting period. Furthermore, it would also have been possible to find the opposite: less improvement through training after the waiting period.

Summary

Overall, the third study provided behavioral and electrophysiological evidence of transfer after phonemic switching fluency training. The behavioral findings revealed a decrease in reaction time mixing costs for the training group while analysis of ERP correlates revealed a change in amplitude of mixing costs at posterior electrode sites.

Implications

As an implication for future studies, findings reveal that a broader training intervention can lead to changes in specific cognitive processes along with neurophysiological evidence. The present results further provide implications of the importance of control conditions in intervention studies. From the findings of study 3, it is not clear what effects may have contributed to a stronger training improvement after the waiting period. However, it shows that further processes may have been involved than have been expected.

Future research

Based on the findings from the third study, there are several future studies that could be implemented. For example, the question could be addressed why we did not find any switch costs at pretesting session, in addition to a lack of training-induced changes in mixing costs at central electrode sites.

From a methodological perspective, more studies are needed that investigate the effects of training combined with electrophysiological measures. Only a few studies included neuroscience to examine the changes in process-based training interventions and such studies are lacking particularly in the field of multi-domain trainings. Furthermore, studies could investigate how training affects the brain across several sessions (Lustig et al., 2009). For example, this could be investigated using frequency-band analysis during verbal fluency performance throughout different training sessions.

At a more general level regarding training interventions, more aspects remain unresolved, for example, how much training is required to find significant training improvements (Lustig et al., 2009). Of course, the efficiency differs across several training programs. However, it would be helpful to know how much can be gained from one session. In addition, the length of the training and the amount of sessions required also differ across all training studies. Moreover, the amount of training sessions is usually determined randomly. More systematic research of required sessions should receive greater attention. A possible approach toward this issue could be by assessing training performance of a few participants individually and more intensively (e.g., Flamigni, 2012).

6.1.4 Overall discussion

The present thesis aimed at investigating a short-term training intervention that would be easy to integrate into everyday lifestyle and thus contributed to the existing knowledge in the field of cognitive training interventions. More precisely, the three studies addressed three main aims. It was attempted to identify the underlying cognitive processes associated with verbal fluency performance (study 1), to investigate training effects in three of these processes and transfer to other untrained tasks using verbal fluency as training task (study 2), and to assess behavioral data and neural correlates on a task-switching paradigm before and after verbal fluency training to investigate the effects of a broad training intervention on specific task-related processes (study 3). Furthermore, this work combined and integrated several different approaches: two theoretical perspectives (study 1), two training approaches (study 2), and two acquisition methods (study 3). This has led to several new insights.

Before designing a verbal fluency training intervention, a more detailed analysis was necessary to identify the cognitive processes that could be targeted by training. In study 1, the results revealed a different pattern of cognitive processes associated with each verbal fluency subtest. Especially, findings on the three phonemic fluency subtests revealed a relatively clear picture of different processes associated with each subtests, with processing speed, shifting and inhibition as the most prominent variables. The three subtests were then used for training in study 2. The findings from this study revealed that phonemic switching fluency training was most likely to influence the improvements throughout training as well as in transfer tasks. Findings from the active control group, however, also pointed to performance improvements in a transfer task. In Study 3 we found that phonemic switching training showed improved performance on specific processes found in an established task-switching paradigm (i.e., mixing costs), which the active control group did not reveal. We therefore assume to have targeted specific processes by this broader verbal fluency training. Furthermore, by combining behavioral and ERP correlates in study 3, we were able to identify associated processes underlying training-induced changes, such as anticipation and selection of relevant task-sets. Thus, verbal fluency training, especially phonemic switching fluency, provides a promising tool for improving cognitive performance in healthy old adults.

Additionally, with the two training studies we further gained insight regarding control groups. For example, in study 2, performance improvement on a transfer task was also found for the active control group. This finding provides evidence for the importance of using an active control group and finding an appropriate activity for the active control group. However, only from the findings of study 3 we know that the active control group did not improve their performance on the task-switching transfer task, neither in behavioral outcomes nor in ERP correlates. This indicates that the control activity did not exhibit an improvement in specific processes of a task-switching paradigm. Moreover in study 3, the wait-list control group revealed more training gains in training conducted after the posttest session. This finding has encouraged us to consider the power of wait-conditions and their role in subsequent training. For example, the waiting period might have triggered further effects, such as motivation, that led to an increase in performance throughout training. In addition, it seems important to consider how the control groups have been recruited. In study 2, the no-contact control group was recruited differently compared to the other groups, while in study 3, all of the participants were randomly assigned to the training, active and wait-list control groups. Unfortunately, several previously mentioned intervention studies used only no-contact control groups. This is a problem because other factors that could explain these findings cannot be ruled out, such as the influence of social contact or familiarization with the testing sessions (Noack et al., 2009). This raises the question whether the same training and transfer effects would have been found in these studies if they compared performance to an active control group. Hence, in the present work we obtained results for both the training and control groups that provided some insights into the changes in behavior and the brain of healthy old adults.

6.2 Outlook

An important aspect relates to the fact that today two major research goals can be identified in the research field of maintaining cognitive fitness in healthy old age. On the one hand, there are theoretical models, which include several factors that have previously been found to be associated with cognitive fitness. For example, Yaffe et al. (2009) compared minor and major cognitive decliners with cognitive maintainers and found that the latter were more likely to be younger, have a high school education, work, not take care of a spouse or child, receive enough social support, live with someone, rate their health as good to excellent, and engage in moderate exercise. Further factors that have been identified as contributing to cognitive fitness are nutrition (Greenwood & Winocur, 2005) and emotions (e.g., subclinical depression in relation to sleep; Sutter et al., in press). Other factors, which might additionally play a role in cognitive training interventions, could be personality and motivational aspects. Other variables should also be considered that have been found to moderate cognitive functions, as for example circadian rhythms (McDaniel, Einstein, & Jacoby, 2008). Hence, a wide range of factors might be embedded in these theoretical models. However, in current research, in general only one or a few of these aspects are singled out and investigated more closely. A study that examined several factors and embedded these in a comprehensive theory in the field of multi-domain training interventions is the Synapse Intervention Trial (Lodi-Smith & Park, 2011, relating to the scaffolding theory of aging).

The second major research goal relates to the mechanisms behind the training interventions and conditions under which they work in order to make specific recommendations to potentially interested candidates. For example, process-based training interventions are needed to create and complete a theory. However, currently there is a lack of specific recommendations that could be drawn from findings of recent studies. Even if such recommendations could be given, they would remain at a general level and might not necessarily correspond to the individual needs of participants.

Consequently, both aspects complex models and more recommendations are needed. Also, more training studies are needed that combine these aspects. For example, in the Baltimore Experience Corps (Carlson et al., 2008) an attempt was made to improve cognitive and physical activity as well as social aspects in a real world session by engaging older adults in a multi-modal activity program (e.g., helping school children with reading, library support, and classroom behavior). However, despite the multi-model orientation, only three training activities with very broad processes that were not further specified were provided. In addition, only three cognitive tasks were used to examine transfer, which is not enough to extract general recommendations. Thus, studies are needed that are based on comprehensive models and that allow predictions on the mechanisms behind the training interventions.

As a first suggestion, future studies could include numerous previously successful training interventions subsumed under a few main domains (e.g., cognitive activity, physical fitness, emotional support, etc.). Each domain would involve combinations of variables that would be known to improve or maintain cognitive fitness. An individual approach could be provided, in that participants could choose interventions, which correspond to their individual needs. Thus, instead of general recommendations, the outcome would involve benefits from training at an individual level. Consequently, this approach could lead to a higher level of motivation and compliance during training, involving minimal effort with maximum outcome. However, each individual choosing a different combination of interventions implies that studies investigating the effects and mechanisms of training interventions at a more fine-grained level would still be needed. Thus, the two complementary aspects would remain; that is, whether to maximize the effects for each individual or to investigate the combination and contribution of different factors. Nevertheless, it becomes apparent that there are other alternatives to investigate cognitive fitness in healthy old age than the methods used at present. As a vision of the future, besides such studies a more complex and empirically tested model would be welcome to ultimately be able to cover all interactions between factors specified above.

7 References

Ardila, A. (2008). On the evolutionary origins of executive functions. Brain and Cognition, 68(1), 92-99. doi: 10.1016/j.bandc.2008.03.003

Aschenbrenner, S., Tucha, O., & Lange, K. (2000). Regensburg Word Fluency Test [Regensburger-Wortflüssigkeits-Test (RWT)]. Göttingen: Hogrefe.

Baldo, J. V., & Shimamura, A. P. (1998). Letter and category fluency in patients with frontal lobe lesions. Neuropsychology, 12(2), 259-267.

Ball, K., Berch, D. B., Helmers, K. F., Jobe, J. B., Leveck, M. D., Marsiske, M., et al. (2002). Effects of cognitive training interventions with older adults: A randomized controlled trial. Jama, 288(18), 2271-2281. doi: 10.1001/jama.288.18.2271

Basak, C., Boot, W. R., Voss, M. W., & Kramer, A. F. (2008). Can training in a real-time strategy video game attenuate cognitive decline in older adults? Psychology and Aging, 23(4), 765-777. doi: 10.1037/a0013494

Berry, A. S., Zanto, T. P., Clapp, W. C., Hardy, J. L., Delahunt, P. B., Mahncke, H. W., et al. (2010). The influence of perceptual training on working memory in older adults. PLoS One, 5(7), e11537. doi: 10.1371/journal.pone.0011537

Bherer, L., Kramer, A. F., Peterson, M. S., Colcombe, S., Erickson, K., & Becic, E. (2005). Training effects on dual-task performance: Are there age-related differences in plasticity of attentional control? Psychology and Aging, 20(4), 695-709. doi: 10.1037/0882-7974.20.4.695

Ble, A., Volpato, S., Zuliani, G., Guralnik, J. M., Bandinelli, S., Lauretani, F., et al. (2005). Executive function correlates with walking speed in older persons: The InCHIANTI study. Journal of the American Geriatrics Society, 53(3), 410-415. doi: 10.1111/j.1532-5415.2005.53157.x

Bolla, K. I., Lindgren, K. N., Bonaccorsy, C., & Bleecker, M. L. (1990). Predictors of verbal fluency (FAS) in the healthy elderly. Journal of Clinical Psychology, 46(5), 623-628. doi: 10.1002/1097-4679(199009)46:5<623

Boot, W. R., & Blakely, D. P. (2011). Mental and physical execise as a means to reverse cognitive aging and enhance well-being. In P. E. Hartman-Stein & A. La Rue (Eds.), Enhancing cognitive fitness in adults. New York: Springer.

Brickman, A. M., Paul, R. H., Cohen, R. A., Williams, L. M., MacGregor, K. L., Jefferson, A. L., et al. (2005). Category and letter verbal fluency across the adult lifespan:

Relationship to EEG theta power. Archives of Clinical Neuropsychology, 20(5), 561-573. doi: 10.1016/j.acn.2004.12.006

Bryan, J., Luszcz, M. A., & Crawford, J. R. (1997). Verbal knowledge and speed of information processing as mediators of age differences in verbal fluency performance among older adults. Psychology and Aging, 12(3), 473-478. doi: 410.1037/0882-7974.1012.1033.1473

Bryan, J., Luszcz, M. A., & Pointer, S. (1999). Executive Function and processing resources as predictors of adult age differences in the implementation of encoding strategies. Aging, Neuropsychology, and Cognition, 6(4), 273-287.

Buschkuehl, M., Jaeggi, S. M., Hutchison, S., Perrig-Chiello, P., Dapp, C., Muller, M., et al. (2008). Impact of working memory training on memory performance in old-old adults. Psychology and Aging, 23(4), 743-753. doi: 10.1037/a0014342

Cabeza, R. (2002). Hemispheric asymmetry reduction in older adults: The HAROLD model. Psychology and Aging, 17(1), 85-100.

Carlson, M. C., Saczynski, J. S., Rebok, G. W., Seeman, T., Glass, T. A., McGill, S., et al. (2008). Exploring the effects of an "everyday" activity program on executive function and memory in older adults: Experience Corps. Gerontologist, 48(6), 793-801.

Cauthen, N. R. (1978). Verbal fluency: Normative data. Journal of Clinical Psychology, 34(1), 126-129.

Cepeda, N. J., Kramer, A. F., & Gonzalez de Sather, J. C. (2001). Changes in executive control across the life span: Examination of task-switching performance. Developmental Psychology, 37(5), 715-730.

Chan, A. S., Butters, N., Salmon, D. P., & McGuire, K. A. (1993). Dimensionality and clustering in the semantic network of patients with Alzheimer's disease. Psychology and Aging, 8(3), 411-419.

Chen, R. Y., Chen, E. Y., Chan, C. K., Lam, L. C., & Lieh-Mak, F. (2000). Verbal fluency in schizophrenia: Reduction in semantic store. Australian and New Zealand Journal of Psychiatry, 34(1), 43-48.

Comalli, P. E., Jr., Wapner, S., & Werner, H. (1962). Interference effects of Stroop color-word test in childhood, adulthood, and aging. Journal of Genetic Psychology, 100, 47-53.

Czernochowski, D. (2011). ERP evidence for scarce rule representation in older adults following short, but not long preparatory intervals. Frontiers in Psychology, 2, 221. doi: 10.3389/fpsyg.2011.00221

Dahlin, E., Neely, A. S., Larsson, A., Bäckman, L., & Nyberg, L. (2008). Transfer of learning after updating training mediated by the striatum. Science, 320(5882), 1510-1512. doi: 10.1126/science.1155466

Dahlin, E., Nyberg, L., Bäckman, L., & Neely, A. S. (2008). Plasticity of executive functioning in young and older adults: Immediate training gains, transfer, and long-term maintenance. Psychology and Aging, 23(4), 720-730. doi: 10.1037/a0014296

De Beni, R., & Palladino, P. (2004). Decline in working memory updating through ageing: Intrusion error analyses. Memory, 12(1), 75-89. doi: 10.1080/09658210244000568

Dempster, F. N. (1992). The rise and fall of the inhibitory mechanism: Toward a unified theory of cognitive development and aging. Developmental Review, 12, 45-75.

Dennis, N. A., & Cabeza, R. (2008). Neuroimaging of healthy cognitive aging. In F. I. Craik & T. A. Salthouse (Eds.), The handbook of aging and cognition. New York: Psychology Press.

Dobbs, A. R., & Rule, B. G. (1989). Adult age differences in working memory. Psychology and Aging, 4(4), 500-503. doi: 10.1037/0882-7974.4.4.500

Dyck, J. L., & Al-Awar Smither, J. (1994). Age differences in computer anxiety: The role of computer experience, gender and education. Journal of Educational Computing Research, 10(3), 238-248.

Edelstein, B. A., & Segal, D. L. (2011). Assessment of emotional and personality disorders in older adults. In K. W. Schaie & S. L. Willis (Eds.), Handbook of the psychology of aging. London: Academic Press.

Elvevåg, B., Weinstock, D. M., Akil, M., Kleinman, J. E., & Goldberg, T. E. (2001). A comparison of verbal fluency tasks in schizophrenic patients and normal controls. Schizophrenia Research, 51(2-3), 119-126.

Epker, M. O., Lacritz, L. H., & Munro Cullum, C. (1999). Comparative analysis of qualitative verbal fluency perfrormance in normal elderly and demented populations. Journal of Clinical and Experimental Neuropsychology, 21(4), 425-435.

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. Emotion, 7(2), 336-353. doi: 10.1037/1528-3542.7.2.336

Fisk, J. E., & Sharp, C. A. (2004). Age-related impairment in executive functioning: Updating, inhibition, shifting, and access. Journal of Clinical and Experimental Neuropsychology, 26(7), 874-890. doi: 10.1080/13803390490510680

Flamigni, A. (2012). Plastizität bei Hochaltrigen: Eine Einzelfallstudie [Plasticity in very old adults: A case study (Unpublished master's thesis)]. Department of Psychology, University of Zurich, Zurich.

Galasko, D., Klauber, M. R., Hofstetter, C. R., Salmon, D. P., Lasker, B., & Thal, L. J. (1990). The Mini-Mental State Examination in the early diagnosis of Alzheimer's disease. Archives of Neurology, 47(1), 49-52.

Gauggel, S., & Birkner, B. (1999). Validität und Reliabilität einer deutschen Version der Geriatrischen Depressionsskala (GDS). Zeitschrift für Klinische Psychologie, 28(1), 18-27. doi: 10.1026//0084-5345.1028.1021.1018.

Glisky, E. L. (2007). Changes in cognitive function in human aging. In D. R. Riddle (Ed.), Brain Aging: Models, Methods, and Mechanisms. Boca Raton: CRC Press.

Goffaux, P., Phillips, N. A., Sinai, M., & Pushkar, D. (2006). Behavioural and electrophysiological measures of task switching during single and mixed-task conditions. Biological Psychology, 72(3), 278-290. doi: 10.1016/j.biopsycho.2005.11. 009

Goffaux, P., Phillips, N. A., Sinai, M., & Pushkar, D. (2008). Neurophysiological measures of task-set switching: Effects of working memory and aging. Journals of Gerontology, Series B, Psychological Sciences and Social Sciences, 63(2), P57-66.

Goh, J. O., & Park, D. C. (2009). Neuroplasticity and cognitive aging: The scaffolding theory of aging and cognition. Restorative Neurology and Neuroscience, 27(5), 391-403. doi: 10.3233/RNN-2009-0493

Grady, C. L., Maisog, J. M., Horwitz, B., Ungerleider, L. G., Mentis, M. J., Salerno, J. A., et al. (1994). Age-related changes in cortical blood flow activation during visual processing of faces and location. The Journal of Neuroscience, 14(3 Pt 2), 1450-1462.

Greenwood, C. E., & Winocur, G. (2005). High-fat diets, insulin resistance and declining cognitive function. Neurobiology of Aging, 26 Suppl 1, 42-45. doi: 10.1016/j.neurobiolaging.2005.08.017

Hasher, L., Stoltzfus, E. R., Zacks, R. T., & Rypma, B. (1991). Age and inhibition. Journal of Experimental Psychology - Learning, Memory, and Cognition, 17(1), 163-169.

Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. H. Bower (Ed.), The Psychology of Learning and Motivation (Vol. 22, pp. 193-225). San Diego, CA: Academic Press.

Head, D., Rodrigue, K. M., Kennedy, K. M., & Raz, N. (2008). Neuroanatomical and cognitive mediators of age-related differences in episodic memory. Neuropsychology, 22(4), 491-507. doi: 10.1037/0894-4105.22.4.491

Helmstaedter, C., Lendt, M., & Lux, S. (2001). Verbaler Lern- und Merkfähigkeitstest [Verbal Learning and Memory Test]. Göttingen: Belz.

Henry, J., & Crawford, J. R. (2005). A meta-analytic review of verbal fluency deficits in depression. Journal of Clinical and Experimental Neuropsychology, 27(1), 78-101. doi: 10.1080/138033990513654

Henry, J. D., & Crawford, J. R. (2004). A meta-analytic review of verbal fluency performance in patients with traumatic brain injury. Neuropsychology, 18(4), 621-628. doi: 10.1037/0894-4105.18.4.621

Henry, J. D., Crawford, J. R., & Phillips, L. H. (2004). Verbal fluency performance in dementia of the Alzheimer's type: A meta-analysis. Neuropsychologia, 42(9), 1212-1222. doi: 10.1016/j.neuropsychologia.2004.02.001

Henry, J. D., Crawford, J. R., & Phillips, L. H. (2005). A meta-analytic review of verbal fluency deficits in Huntington's disease. Neuropsychology, 19(2), 243-252. doi: 10.1037/0894-4105.19.2.243

Hertzog, C., Kramer, A. F., Wilson, R. S., & Lindenberger, U. (2009). Enrichment effects on adult cognitive development. Psychological Science in the Public Interest, 9, 1-65.

Horn, J. L., & Cattell, R. B. (1967). Age differences in fluid and crystallized intelligence. Acta Psychologica, 26(2), 107-129.

Hultsch, D. F., Hertzog, C., Small, B. J., McDonald-Miszczak, L., & Dixon, R. A. (1992). Short-term longitudinal change in cognitive performance in later life. Psychology and Aging, 7(4), 571-584.

Jäncke, L. (2009). The plastic human brain. Restorative Neurology and Neuroscience, 27(5), 521-538.

Karbach, J., & Kray, J. (2009). How useful is executive control training? Age differences in near and far transfer of task-switching training. Developmental Science, 12(6), 978-990. doi: 10.1111/j.1467-7687.2009.00846.x

Kempler, D., Teng, E. L., Dick, M., Taussig, I. M., & Davis, D. S. (1998). The effects of age, education, and ethnicity on verbal fluency. Journal of the International Neuropsychological Society, 4(6), 531-538.

Kemps, E., & Wilsdon, A. (2010). Preliminary evidence for a role for impulsivity in cognitive disinhibition in bulimia nervosa. Journal of Clinical and Experimental Neuropsychology, 32(5), 515-521.

Kramer, A. F., Hahn, S., & Gopher, D. (1999). Task coordination and aging: Explorations of executive control processes in the task switching paradigm. Acta Psychologica, 101(2-3), 339-378.

Kray, J. (2006). Task-set switching under cue-based versus memory-based switching conditions in younger and older adults. Brain Research, 1105(1), 83-92. doi: 10.1016/j.brainres.2005.11.016

Kray, J., Li, K. Z., & Lindenberger, U. (2002). Age-related changes in task-switching components: The role of task uncertainty. Brain and Cognition, 49(3), 363-381.

Kray, J., & Lindenberger, U. (2000). Adult age differences in task switching. Psychology and Aging, 15(1), 126-147.

Kroner-Herwig, B., Hebing, G., van Rijn-Kalkmann, U., Frenzel, A., Schilkowsky, G., & Esser, G. (1995). The management of chronic tinnitus-comparison of a cognitive-behavioural group training with yoga. Journal of Psychosomatic Research, 39(2), 153-165.

Laux, L., Glanzmann, P., Schffner, P., & Spielberger, C. D. (1981). The State-Trait-Anxiety Inventory [Das State-Trait-Angstinventar (STAI)]. Weinheim, Germany: Beltz.

Lavric, A., Mizon, G. A., & Monsell, S. (2008). Neurophysiological signature of effective anticipatory task-set control: A task-switching investigation. The European Journal of Neuroscience, 28(5), 1016-1029. doi: 10.1111/j.1460-9568.2008.06372.x

Lehrl, S. (1977). Mehrfachwahl-Wortschatz-Intelligenztest [MWT-B]: Straube-Verlag.

Li, S. C., Schmiedek, F., Huxhold, O., Rocke, C., Smith, J., & Lindenberger, U. (2008). Working memory plasticity in old age: Practice gain, transfer, and maintenance. Psychology and Aging, 23(4), 731-742. doi: 10.1037/a0014343

Lindenberger, U. (2008). Was ist kognitives Altern? Begriffsbestimmung und Forschungstrends. In U. Staudinger & H. Häfinger (Eds.), Was ist Alter(n)? (pp. 69-82). Heidelberg: Springer.

Lodi-Smith, J., & Park, D. C. (2011). Synapse: A clinical trial examining the impact of actively engaging the aging mind. In P. E. Hartman-Stein & A. La Rue (Eds.), Enhancing cognitive fitness in adults. New York: Springer.

Lustig, C., Shah, P., Seidler, R., & Reuter-Lorenz, P. A. (2009). Aging, training, and the brain: A review and future directions. Neuropsychology Review, 19(4), 504-522. doi: 10.1007/s11065-009-9119-9

Luszcz, M. (2011). Executive function and cognitive aging. In K. W. Schaie & S. L. Willis (Eds.), Handbook of the psychology of aging. London: Academic Press.

Maclin, E. L., Mathewson, K. E., Low, K. A., Boot, W. R., Kramer, A. F., Fabiani, M., et al. (2011). Learning to multitask: Effects of video game practice on electrophysiological indices of attention and resource allocation. Psychophysiology, 48(9), 1173-1183. doi: 10.1111/j.1469-8986.2011.01189.x

Manzi, A., Nessler, D., Czernochowski, D., & Friedman, D. (2011). The development of anticipatory cognitive control processes in task-switching: An ERP study in children, adolescents, and young adults. Psychophysiology, 48(9), 1258-1275. doi: 10.1111/j.1469-8986.2011.01192.x

Martin, M., Clare, L., Altgassen, A. M., Cameron, M. H., & Zehnder, F. (2011). Cognition-based interventions for healthy older people and people with mild cognitive impairment. Cochrane Database of Systematic Reviews(1), CD006220. doi: 10.1002/14651858.CD006220.pub2

Mayr, U. (2001). Age differences in the selection of mental sets: The role of inhibition, stimulus ambiguity, and response-set overlap. Psychology and Aging, 16(1), 96-109.

McDaniel, M. A., Einstein, G. O., & Jacoby, L. L. (2008). New considerations in aging and memory: The glass may be half full. In F. I. Craik & T. A. Salthouse (Eds.), The handbook of aging and cognition. New York: Psychology Press.

Meiran, N. (2000). Modeling cognitive control in task-switching. Psychological Research, 63(3-4), 234-249.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. Cognitive Psychology, 41(1), 49-100. doi: 10.1006/cogp.1999.0734

Monsch, A. U., Bondi, M. W., Butters, N., Salmon, D. P., Katzman, R., & Thal, L. J. (1992). Comparisons of verbal fluency tasks in the detection of dementia of the Alzheimer type. Archives of Neurology, 49(12), 1253-1258.

Monsell, S. (2003). Task switching. Trends in Cognitive Science, 7(3), 134-140.

Morris, S. B., & DeShon, R. P. (2002). Combining effect size estimates in meta-analysis with repeated measures and independent-groups designs. Psychological Methods, 7(1), 105-125.

Noack, H., Lovden, M., Schmiedek, F., & Lindenberger, U. (2009). Cognitive plasticity in adulthood and old age: Gauging the generality of cognitive intervention effects. Restorative Neurology and Neuroscience, 27(5), 435-453. doi: 10.3233/RNN-2009-0496

Noice, H., Noice, T., & Staines, G. (2004). A short-term intervention to enhance cognitive and affective functioning in older adults. Journal of Aging and Health, 16(4), 562-585. doi: 10.1177/0898264304265819

Nyberg, L., & Bäckman, L. (2004). Cognitive aging: A view from brain imaging. In R. A. Dixon, L. Bäckman & L. G. Nilsson (Eds.), New frontiers in cognitive aging (pp. 135-160). New York: Oxford University Press.

Oswald, W. D., & Fleischmann, U. M. (Eds.). (2006). Neuropsychological Aging Inventory (NAI). Göttingen: Hogrefe.

Park, D., & Bischof, G. N. (2011). Neuroplasticity, aging, and cognitive function. In K. W. Schaie & S. L. Willis (Eds.), Handbook of the psychology of aging. London: Academic Press.

Park, D. C., Lautenschlager, G., Hedden, T., Davidson, N. S., Smith, A. D., & Smith, P. K. (2002). Models of visuospatial and verbal memory across the adult life span. Psychology and Aging, 17(2), 299-320.

Park, D. C., & Reuter-Lorenz, P. (2009). The adaptive brain: Aging and neurocognitive scaffolding. Annual Review of Psychology, 60, 173-196. doi: 10.1146/annurev.psych.59.103006.093656

Parkin, A. J., Walter, B. M., & Hunkin, N. M. (1995). Relationships between normal aging, frontal lobe function, and memory for temporal and spatial information Neuropsychology Review, 9(3), 304-312.

Perret, E. (1974). The left frontal lobe of man and the suppression of habitual responses in verbal categorical behaviour. Neuropsychologia, 12(3), 323-330.

Phillips, L. H. (1999). Age and individual differences in letter fluency. Developmental Neuropsychology, 15(2), 249-267.

Randolph, C., Braun, A. R., Goldberg, T. E., & Chase, T. N. (1993). Semantic fluency in Alzheimer's, Parkinson's, and Huntington's disease: Dissociation of storage and retrieval failures. Neuropsychology, 7, 82-88.

Reitan, R. M. (1971). Trail making test results for normal and brain-damaged children. Perceptual and Motor Skills, 33(2), 575-581.

Rey, A. (1958, 1964). L'examen Clinique en Psychologie. Paris: PUF.

Rogers, R. D., & Monsell, S. (1995). Costs of a predictable switch between simple cognitive tasks. Journal of Experimental Psychology. General, 124(2), 207-231.

Rosen, V. M., & Engle, R. W. (1997). The role of working memory capacity in retrieval. Journal of Experimental Psychology, 126(3), 211-227.

Ruff, R. M., Light, R. H., Parker, S. B., & Levin, H. S. (1997). The psychological construct of word fluency. Brain and Language, 57(3), 394-405.

Rushworth, M. F., Passingham, R. E., & Nobre, A. C. (2002). Components of switching intentional set. Journal of Cognitive Neuroscience, 14(8), 1139-1150. doi: 10.1162/089892902760807159

Salthouse, T. A. (1993). Speed and knowledge as determinants of adult age differences in verbal tasks. Journals of Gerontology, 48(1), P29-36.

Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. Psychological Review, 103(3), 403-428. doi: 10.1037/0033-295X.103.3.403

Salthouse, T. A. (2005). Relations between cognitive abilities and measures of executive functioning. Neuropsychology, 19(4), 532-545. doi: 10.1037/0894-4105.19.4.532

Salthouse, T. A., Atkinson, T. M., & Berish, D. E. (2003). Executive functioning as a potential mediator of age-related cognitive decline in normal adults. Journal of Experimental Psychology: General, 132(4), 566-594. doi: 10.1037/0096-3445.132.4.566

Sedek, G., Brzezicka, A., & Von Hecker, U. (2010). The unique cognitive limitation in subclinical depression: The impairment of mental model construction In A. Gruszka, G. Matthews, & B. Szymura (Ed.), Handbook of individual differences in cognition (Vol. 4, pp. 335-352). New York: Springer.

Sheikh, J. I., & Yesavage, J. A. (1986). Geriatric Depression Scale (GDS): Recent evidence and development for a shorter version. Clinical Gerontologist, 5(1-2), 165-173. doi: 110.1300/J1018v1305n1301_1309.

Shores, E. A., Carstairs, J. R., & Crawford, J. R. (2006). Excluded letter fluency test (ELF): Norms and test-retest reliabilty data for healthy young adults. Brain Impairment, 7(1), 26-32.

Smith, E. E., & Jonides, J. (1999). Storage and executive processes in the frontal lobes. Science, 283(5408), 1657-1661.

Sohn, M. H., Ursu, S., Anderson, J. R., Stenger, V. A., & Carter, C. S. (2000). The role of prefrontal cortex and posterior parietal cortex in task switching. Proceedings of the National Academy of Sciences of the United States of America, 97(24), 13448-13453. doi: 10.1073/pnas.240460497

Steffens, D. C., Skoog, I., Norton, M. C., Hart, A. D., Tschanz, J. T., Plassman, B. L., et al. (2000). Prevalence of depression and its treatment in an elderly population: The Cache County study. Archives of General Psychiatry, 57(6), 601-607.

Stern, Y. (2002). What is cognitive reserve? Theory and research application of the reserve concept. Journal of the International Neuropsychological Society, 8(3), 448-460.

Stine-Morrow, E. A., Parisi, J. M., Morrow, D. G., & Park, D. C. (2008). The effects of an engaged lifestyle on cognitive vitality: A field experiment. Psychology and Aging, 23(4), 778-786. doi: 10.1037/a0014341

Stuss, D. T., & Knight, R. T. (2002). Principles of frontal lobe function. New York: Oxford University Press.

Sutin, A. R., Terracciano, A., Kitner-Triolo, M. H., Uda, M., Schlessinger, D., & Zonderman, A. B. (2011). Personality traits prospectively predict verbal fluency in a lifespan sample. Psychology and Aging, 26(4), 994-999. doi: 10.1037/a0024276

Sutter, C., Zöllig, J., Allemand, M., & Martin, M. (in press). Sleep quality and cognitive function in healthy old age: The moderating role of subclinical depression. Neuropsychology.

Sutter, C., Zöllig, J., & Martin, M. (in press). Plasticity of verbal fluency in older adults: A 90 minutes telephone-based intervention. Gerontology.

Tombaugh, T. N., Kozak, J., & Rees, L. (1999). Normative data stratified by age and education for two measures of verbal fluency: FAS and animal naming. Archives of Clinical Neuropsychology, 14(2), 167-177.

Tomer, R., & Levin, B. E. (1993). Differential effects of aging on two verbal fluency tasks. Perceptual and Motor Skills, 76(2), 465-466.

Troyer, A. K., Moscovitch, M., & Winocur, G. (1997). Clustering and switching as two components of verbal fluency: Evidence from younger and older healthy adults. Neuropsychology, 11(1), 138-146.

Unsworth, N., Spillers, G. J., & Brewer, G. A. (2011). Variation in verbal fluency: A latent variable analysis of clustering, switching, and overall performance. Quaterly Journal of Experimental Psychology, 64(3), 447-466. doi: 10.1080/17470218.2010.505292

Van der Elst, W., Van Boxtel, M. P., & Jolles, J. (2012). Occupational activity and cognitive aging: A case-control study based on the Maastricht Aging Study. Experimental Aging Research, 38(3), 315-329. doi: 10.1080/0361073X.2012.672137

Verhaeghen, P., & Cerella, J. (2002). Aging, executive control, and attention: A review of meta-analyses. Neuroscience and Biobehavioral Reviews, 26(7), 849-857.

Verhaeghen, P., & Marcoen, A. (1996). On the mechanisms of plasticity in young and older adults after instruction in the method of loci: Evidence for an amplification model. Psychology and Aging, 11(1), 164-178.

Verhaeghen, P., Marcoen, A., & Goossens, L. (1992). Improving memory performance in the aged through mnemonic training: A meta-analytic study. Psychology and Aging, 7(2), 242-251.

Vygotsky, L. S. (1962). Thoughts and language. Cambridge, MA: MIT Press.

Wecker, N. S., Kramer, J. H., Hallam, B. J., & Delis, D. C. (2005). Mental flexibility: Age effects on switching. Neuropsychology, 19(3), 345-352. doi: 10.1037/0894-4105.19.3.345

Weiss, E. M., Siedentopf, C., Hofer, A., Deisenhammer, E. A., Hoptman, M. J., Kremser, C., et al. (2003). Brain activation pattern during a verbal fluency test in healthy male and female volunteers: A functional magnetic resonance imaging study. Neuroscience Letters, 352(3), 191-194.

West, R. L. (1996). An application of prefrontal cortex function theory to cognitive aging. Psychological Bulletin, 120(2), 272-292. doi:210.1037/0033-2909.1120.1032.1272.

Wierenga, C. E., Benjamin, M., Gopinath, K., Perlstein, W. M., Leonard, C. M., Rothi, L. J., et al. (2008). Age-related changes in word retrieval: Role of bilateral frontal and subcortical networks. Neurobiology of Aging, 29(3), 436-451. doi: 10.1016/j.neurobiolaging.2006.10.024

Willis, S. L., Tennstedt, S. L., Marsiske, M., Ball, K., Elias, J., Koepke, K. M., et al. (2006). Long-term effects of cognitive training on everyday functional outcomes in older adults. Jama, 296(23), 2805-1814. doi: 10.1001/jama.296.23.2805

Woods, W. A. (1975). What's in a link: Foundations for semantic networks. In D. G. Bobrow & A. M. Collins (Eds.), Representation and understanding: Studies in cognitive science (pp. 35-82). London: Academic Press.

Yaffe, K., Fiocco, A. J., Lindquist, K., Vittinghoff, E., Simonsick, E. M., Newman, A. B., et al. (2009). Predictors of maintaining cognitive function in older adults: The Health ABC study. Neurology, 72(23), 2029-2035. doi: 10.1212/WNL.0b013e3181a92c36

Yesavage, J. A., Sheikh, J. I., Friedman, L., & Tanke, E. (1990). Learning mnemonics: Roles of aging and subtle cognitive impairment. Psychology and Aging, 5(1), 133-137.

Zelinski, E. M., Dalton, S. E., & Smith, G. E. (2011). Consumer-based brain fitness programs. In P. E. Hartman-Stein & A. La Rue (Eds.), Enhancing cognitive fitness in adults. New York: Springer.

Zimmermann, P., & Fimm, B. (2007). Test of Attentional Performance (TAP). Würselen: Psytest.

Zöllig, J., Mattli, F., Sutter, C., Aurelio, A., & Martin, M. (2012). Plasticity of prospective memory through a familiarization intervention in old adults. Aging, Neuropsychology, and Cognition, 19(1-2), 168-194. doi: 10.1080/13825585.2011.633160

8 Zusammenfassung

Zu den am häufigsten genannten altersbedingten negativen Veränderungen in kognitiven Funktionen gehören exekutive Funktionen, wie Shifting und Inhibition, sowie die Verarbeitungsgeschwindigkeit als Basisfunktion exekutiver Funktionen. Das Interesse ist gross, diese Funktionen im Alter mit Hilfe kognitiver Trainings zu erhalten oder zu verbessern. Jedoch sind die Befunde bestehender Studien kaum vergleichbar, da bislang unterschiedliche Paradigmen eingesetzt wurden, um die Effekte dieser kognitiven Trainings zu untersuchen. In der vorliegenden Arbeit wurde ein Paradigma entwickelt, welches den Vergleich von verschiedenen Trainings exekutiver Funktionen ermöglicht. Durch Variation der Instruktion einer Testaufgabe konnten wir Folgendes untersuchen: (1) die zugrundeliegenden Prozesse verschiedener Untertests einer Testaufgabe, (2) das Ausmass der Trainingsgewinne und den Transfer auf untrainierte Aufgaben nach Verwendung von drei Untertests als Trainingsaufgabe (3) sowie ob Transfereffekte des erfolgreichsten Trainings mit Veränderungen in neurophysiologischen Korrelaten einhergehen. Das zentrale Element in der ersten Studie war die Aufgabe verbale Flüssigkeit (verbal fluency), welche erfordert so viele Wörter wie möglich nach einem vorgegebenen Kriterium zu nennen. Es wurde untersucht, ob durch Variation der Instruktion unterschiedliche kognitive Prozesse mit der Aufgabe assoziiert sind. Die Resultate der ersten Studie zeigten, dass alle verbalen Flüssigkeitstests ein unterschiedliches Muster von assoziierten kognitiven Prozessen aufwiesen. Vor allem bei drei phonematischen verbalen Flüssigkeitstests, die als Kriterium einen Buchstaben beinhalten, hing die Leistung in der Aufgabe je nach Instruktion mit der Verarbeitungsgeschwindigkeit, Shifting oder Inhibition zusammen. In der zweiten Studie wurden Trainingsgewinne und Transfereffekte nach Verwendung dieser drei Aufgaben in einem dreiwöchigen telefonbasierten Training untersucht. Die grössten Trainingsgewinne und Transfereffekte zeigten sich nach intensivem Training der Aufgabe, die vor allem den Prozess des Shiftings beanspruchte. In der dritten Studie wurde untersucht, ob sich die Trainingseffekte auch in Prozessen einer Aufgabenwechsel-Aufgabe und zusätzlichen Veränderungen in der Hirnaktivität zeigten. Neben einer verbesserten Leistung in mixing costs, das heisst dem Anstieg der Reaktionszeit wenn zwei Aufgaben bearbeitet werden im Vergleich zu wenn nur eine bearbeitet wird, wurden auch trainingsbedingte Veränderungen in parietalen Elektroden gefunden, welche mit der Auswahl des relevanten Aufgabensets in Verbindung gebracht werden. Zusammenfassend konnte in dieser Arbeit mittels eines

Paradigmas, bei welchem die zugrundeliegenden Prozesse identifiziert wurden, das erfolgversprechendste Training exekutiver Funktionen ermittelt werden. Implikationen dieser Befunde und Vorschläge für zukünftige Studien werden diskutiert.